# CONSERVATION BIOLOGY OF THE SPECKLED CHUB COMPLEX (CYPRINIDAE: CF. *MACRHYBOPSIS AESTIVALIS*) IN THE ARKANSAS RIVER BASIN

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TABLE OF CONTENTS

LIST OF TABLES

## LIST OF FIGURES

Figure Page

# CHAPTER I

## DISTRIBUTIONAL STATUS OF THE SPECKLED CHUB COMPLEX (CYPRINIDAE: CF. *MACRHYBOPSIS AESTIVALIS*) IN THE ARKANSAS RIVER BASIN

### INTRODUCTION

In this paper, I report the historical distributions and present status of two species of the speckled chub complex, *Macrhybopsis tetranema* and *M. hyostoma*, in the Arkansas River Basin. Until recently, speckled chubs in the Arkansas River Basin and elsewhere (Wallace, 1980) were referred to as a single, wide-ranging, geographically variable species (*M.* [= *Hybopsis*] *aestivalis*). However, several workers had suggested that the specific epithet may encompass more than one species (Miller and Robison, 1973; Robison and Buchanan, 1988; Page and Burr, 1991). Based on morphological data, D. Eisenhour (pers. comm.) recognizes several species within the complex, two of which inhabit the Arkansas River Basin. *Macrhybopsis tetranema* is endemic to the basin, where, historically, it occurred in upstream reaches of the Arkansas River and its larger, western tributaries. The second species, *M. hyostoma*, is more widespread, occurring in middle and lower reaches of the Arkansas River mainstem and its western tributaries, and elsewhere in the Mississippi River System.

*Macrhybopsis tetranema* has a conical shaped head, tiny, nearly round eyes, and a pair of posterior barbels that are longer than the length of the orbit along with a pair of anterior barbels more than half the orbit length. *Macrhybopsis hyostoma* has a rounded head with a hump over the nares, oval eyes, and a pair of posterior barbels that are shorter than the length of the orbit along with a pair of anterior barbels less than half the orbit length.

The present work grew out of concern (Cross and Moss, 1987; Williams et al., 1989) for the status of the previously recognized "Arkansas River speckled chub" *M.* (= *Hybopsis*) *aestivalis tetranemus*, which encompassed both of the presently recognized speckled chub species in the Arkansas River Basin. This nominal taxon has declined over large portions of the Arkansas River Basin during the past 30 years, as have other prairie-stream taxa, including cyprinid fishes (Cross and Moss, 1987; Larson, 1991; Echelle et al., 1995) and bivalve mollusks (Distler and Bleam, 1995). In general, decline of the native prairie-stream fauna has been attributed to effects of ground-water removal for irrigation and reservoir construction, which have changed base-flow levels (including summertime dewatering of some upstream reaches) and altered the periodicity and intensity of flooding over large portions of the drainage (Cross and Moss, 1987; Wahl and Wahl, 1988; Larson, 1991). Such changes alter substrata composition, sediment movement, and channel morphometry (McLaughlin, 1947; Schumm, 1960; Williams and Wolman, 1984).

Despite alterations in flow regime and the potential effects on habitat characteristics, it is difficult to explain declines of individual species in the basin. A complicating observation is that the declines of different cyprinid species have not been synchronous. For example, declines of "Arkansas River speckled chub" and Arkansas River shiner (Notropis girardi) do not show the same spatial pattern in the basin (Larson, 1991). This asynchrony may be explained by environmental and demographic stochasticity, together with species specific differences in life history.

In this paper, I examine the role of barriers to dispersal (artificial impoundments) in explaining the decline of speckled chub. This is a potentially important factor in the decline of stream fishes (Sheldon, 1988; Bestgen and Platania, 1990, 1991). In a particularly well-documented example, Winston et al. (1991) attributed absence of speckled chub in a portion of the Red River drainage to local extirpation and presence of a reservoir preventing recolonization from downstream. Do artificial barriers to dispersal help explain patterns of disappearance of speckled chub in the Arkansas River Basin? If so, then changes in habitat quality resulting from altered flow regimes are only part of the explanation for losses of populations in the basin. Models of interaction between local populations suggest two ways that, by acting as barriers to dispersal, reservoirs can contribute to declines in the distributional range and eventual extinction of a species: 1) First, in the metapopulation model, barriers to recolonization cause distributional declines because local extirpations are not followed by recolonization (Levins, 1970). 2) Second, in the "source-sink" model (Pulliam, 1988), some specific local populations ("sinks") occupy inferior habitat and persist only because of dispersal from other local populations ("sources"). Reservoirs might separate sinks from sources, resulting in losses of historical populations. A third way that artificial barriers can contribute to local extirpations is by blocking dispersal into refugial areas during harsh conditions (Schlosser, 1995; Bestgen and Platania, 1991).

The natural riverine environments in larger, western tributaries of the Arkansas River typically have wide, shallow, unshaded channels with sand and gravel bottoms and extreme variation in water levels, turbidity, temperature, and salinity (Matthews and Hill, 1980; Matthews, 1988). A common life-history feature of four of the declining cyprinids in such habitats is that they all seem dependent on late spring or summer floods for spawning: speckled chubs (Bottrell et al., 1964; S. Platania, pers. comm.), Arkansas River shiners (Moore, 1944; Bestgen et al., 1989; S. Platania, pers. comm.), and plains minnows *Hybognathus placitus* (Taylor and Miller, 1990; S. Platania, pers. comm.). Such species spawn during flood conditions, releasing semi-buoyant eggs that drift downstream with the current. After hatching, larvae drift downstream as they develop and later life stages disperse upstream. Short-lived cyprinids with this life history pattern would be particularly susceptible to population losses as a result of drought, changes in flow regime, and barriers to dispersal.

Historically, prairie fishes probably were susceptible to periods of suboptimal conditions and local extinctions in their relatively unpredictable environment. For such species, the natural extinction/recolonization dynamic of the metapopulation model and dispersal in the source-sink model may be particularly important in persistence of local populations. Further, dispersal as a mechanism of persistence may have become increasingly important as a result of anthropogenic change and associated declines in habitat quality. Levins (1970) noted that the extinction/recolonization dynamic can prevent extinction even when environmental conditions are unsuitable throughout the range of a metapopulation.

## MATERIALS and METHODS

The historical distributions of *M. tetranema* and *M. hyostoma* in the Arkansas River Basin were delimited by examination of museum specimens (Appendix A) by D. Eisenhour (pers. comm.) and/or by myself. Temporal patterns in occurrence of the species were evaluated from the museum records, published and unpublished literature (cited where applicable), and unpublished field-notes (G. A. Moore, F. B. Cross, J. Pigg, R. D. Larson) deposited in the Oklahoma State University Vertebrate Collections. All references to specimens deposited in institutional collections follow the symbolic codes of Leviton et al. (1985) and Poss and Collette (1995).

The distribution and number of samples that I made in assessing the status of speckled chubs in the Arkansas River Basin in 1991-1997 are summarized in Table I. I used nylon-seines (3.6- or 7.6-m long, 1.8-m deep, with 3.2-mm mesh) in all sampling. Efforts were made to locate and sample all historical collection localities for speckled chubs except in some instances where these sites were in close proximity to each other. Initially, I sampled all available habitats (e.g., pools, runs, and backwaters) at every site. However, I soon recognized, as others have (Trautman, 1957; Pflieger, 1975; Peters et al., 1989; Luttrell, 1997), that speckled chubs prefer main channel areas with patches of pea-sized gravel substrata. Subsequently, I sampled sites by locating these conditions and then making four or more downstream seine-hauls in, or adjacent to, the main channel. Speckled chubs, and other selected species, were preserved and deposited in the Oklahoma State University Collection of Vertebrates (OSUS).

To examine effects of reservoirs, I compared cumulative number of reservoirs through time with the cumulative number of extinctions in different segments of stream. Year-of-completion for reservoirs was taken from Moody et al. (1985) and time-of-extinction was based on the last recorded collection of the species from the particular segment of the drainage. I also computed Pearson product-moment correlations between year of presumed extirpation for a segment of the drainage and year-of-completion for the reservoir that separated the segment from an area where a population still persisted.

# RESULTS

## History of Occurrence

The following is an account of the history of occurrence of the two species of speckled chub in the major drainages of the Arkansas River Basin. I then examine the relationship between extirpations and the construction of water projects that may have represented barriers to migration and recolonization.

The historical distributions of *M. tetranema* and *M. hyostoma* in the Arkansas River Basin are shown in Figure 1. The present distribution of both species, based on the capture of 545 *M. hyostoma* and 112 *M. tetranema* in 39 collecting-visits to 30 sites, is illustrated in Figure 2. Reservoirs and dams referred to herein are shown in Figure 2. Sampling efforts (323 visits to 187 sites) in Colorado, Kansas, New Mexico, Oklahoma, and Texas are summarized in Table I; locality information for each sample site is given in Appendix B.

### Arkansas River

A single specimen of *M. tetranema* is known from the Arkansas River in Colorado (Jordan, 1891); there are no records of *M. hyostoma* from the state. Intensive collecting (1979-1981) by C. Loeffler et al. (in litt.) failed to find the species in the Arkansas River drainage of Colorado. I made two collections in Colorado during 1993, one just downstream of John Martin Dam (Bent Co.) and a second near Lamar (Prowers Co.), neither of which contained speckled chubs. Historical data are too sparse to determine whether speckled chubs ever were abundant in Colorado or when they disappeared from the state.

In Kansas, records of M. tetranema are known from near Garden City (Finney Co.) downstream to Wichita (Sedgwick Co.). Collections made between the Colorado-Kansas border and Wichita in the 1970s and 1980s (Cross and Moss, 1987; Eberle et al., 1993), and my collections from five sites in 1993 did not contain speckled chubs. Disappearance of M. tetranema from this region occurred sometime after 1958 (KU 3938; 1 specimen) and appears related to streamflow reductions caused by reservoir construction and surface water diversion for irrigation (Cross and Moss, 1987).

Museum records indicate that M. tetranema co-occurred with M. hyostoma in the Arkansas River mainstem downstream of Wichita (Sedgwick, Co., Kansas) to the Kansas-Oklahoma border (KU 8311; 15 M. tetranema and 12 M. hyostoma). I sampled three sites from Wichita to the state-line and collected five M. tetranema NE of Oxford (Sumner Co.) in 1992 (OSUS 25309) and eight (OSUS 26319) in 1993. I failed to find M. hyostoma in this stream reach. Only a single specimen of *M. hyostoma* (KU 21704; collected in 1984) has been taken from this stream reach since completion of Kaw Reservoir (Kay/Osage Co., Oklahoma) in 1976. The continued persistence of *M. tetranema* and the apparent absence of *M. hyostoma* suggests that persistence of *M. hyostoma* in this area may have been dependent on dispersal from downstream, now precluded by Kaw Reservoir.

In Oklahoma, a single specimen of *M. tetranema* (OKMNH 39032; 1960) is known from the Arkansas River near its confluence with the Cimarron River; all other known records of speckled chubs from the Arkansas River mainstem in Oklahoma have been *M. hyostoma* (Appendix A). I made five visits to three sites on the Arkansas River between Kaw and Keystone reservoirs and collected *M. hyostoma* at all three sites. I also did not find the species at three shoreline sites sampled within Keystone Reservoir.

Downstream of Keystone Reservoir, I collected 7 *M. hyostoma* near Sand Springs (Tulsa Co.) and 2 near Bixby (Tulsa Co.), and failed to find the species farther downstream near Haskell (Muskogee Co.). Recent collections by J. Pigg (unpubl. data) of single specimens of *M. hyostoma* (OSUS 26770, 26769, and 27508) from the McClellan-Kerr Navigation System near Muskogee (Muskogee Co.) and just downstream of the W. D. Mayo Lock and Dam (Le Flore Co.) and from the lower Illinois River (Sequoyah Co.) indicate persistence of sparse populations in some areas of the lower Arkansas River in Oklahoma.

Robison and Buchanan (1988) reported only three historical records of speckled chub from the Arkansas River in Arkansas, but noted that, in the 1880s the species was abundant in the river near Fort Smith. Further, they indicated that "recent surveys of the Arkansas River . . . [by two different researchers] have failed to produce a single specimen. Numerous collections at Fort Smith during the last 16 years . . . [also failed to produce] speckled chubs." Speckled chub were last taken from the Arkansas River near Dardanelle (Pope Co.; OSUS 7224) in 1963, prior to completion of Dardanelle Lock and Dam in 1966 and Ozark Lock and Dam in 1969. The species appears to have been extirpated from the Arkansas River mainstem in Arkansas, possibly a result of streamflow regulation by the McClellan-Kerr Navigation System. Completed in 1971, this 732-km navigable waterway, produced by an extensive series of lock and dam facilities, extends from near Catoosa, Oklahoma downstream to the Mississippi River.

Ninnescah River drainage

There are records of *M. tetranema* from the North Fork, South Fork, and lower Ninnescah rivers in south-central Kansas; both *M. hyostoma* and *M. tetranema* inhabited the lower Ninnescah River. However, M. tetranema appears to have been more widespread (6 collections; 161 specimens) and abundant than M. hyostoma (1 collection, KU 8285; 1 specimen collected in 1964). Collections by F. B. Cross (pers. comm.) in the mid-1960s suggest that M. tetranema was declining in the drainage by 1967. I made 14 collecting-visits to the three major streams in the drainage, as follows: 1) 10 visits to five sites on the South Fork of the Ninnescah River from Pratt (Pratt Co.) downstream to Cheney (Sedgwick Co.); 2) one visit to a site on the North Fork of the Ninnescah River upstream of Cheney Reservoir (Reno Co.) and one to a site downstream of Cheney Reservoir (Sedgwick Co.); and 3) one visit to two sites on the lower Ninnescah River (Sedgwick and Sumner counties). I captured 37 specimens of M. tetranema in three visits to a site on the South Fork of the Ninnescah River near Kingman (Kingman Co.); no specimens of M. tetranema or M. hyostoma were encountered elsewhere in the drainage. Cross et al. (in litt.) examined streamflows for a United States Geological Survey (USGS) station near Peck (Sumner Co.) and found no changes (e.g., reduced intensity of floods) that might explain the decline of speckled chub. Although there have been no obvious changes in stream-habitat conditions in the Ninnescah River drainage since the mid-1960s, base streamflow, water clarity, and the abundance of sight-feeding fishes (e.g., walleye and white bass) have apparently increased since completion of Cheney Reservoir in 1964 (F. B. Cross et al., in litt.).

Salt Fork of the Arkansas River drainage

Museum records show that *M. tetranema* inhabited the Salt Fork of the Arkansas (Salt Fork) and Medicine Lodge rivers upstream of Great Salt Plains Reservoir in north-central Oklahoma; there are no records of *M. hyostoma* from these stream reaches. *Macrhybopsis tetranema* was taken from Kansas localities on the Medicine Lodge River in 1958 and the Salt Fork River in 1964; however, subsequent collections upstream of Great Salt Plains Reservoir in 1979, 1983, 1987, 1991, and 1995 (F. B. Cross et al., in litt.; Eberle et al., 1989; Larson, 1991; Ashbaugh et al., 1996) did not contain the species. From 1991 through 1994, I sampled the Medicine Lodge River at six sites (13 collections) and the Salt Fork River at eight sites (10 collections) without finding *M. tetranema*. The disappearance of *M. tetranema* upstream of Great Salt Plains Reservoir between 1964 and 1983 may be related to a period of unusually low streamflows. Maximum mean daily discharge during the May-August spawning period were less than 1,000 CFS in 1964 and 1966-1968 (Fig. 3). At no other time in the period of record (1938-1983) was maximum mean daily discharge less that 1,000 CFS for two consecutive spawning seasons. A single collection of 11 M. tetranema (OKMNH 29157) was made immediately downstream of Great Salt Plains Reservoir in 1949. This the only known record of the species downstream of the present Great Salt Plains Reservoir (completed in 1941).

Macrhybopsis hyostoma has been taken from the Salt Fork of the Arkansas River from just downstream of the present Great Salt Plains Reservoir to its juncture with the Arkansas River in north-central Oklahoma. In this study, I made 19 samples at 11 sites between the reservoir and the mouth of the river; M. hyostoma occurred at 10 sites from near Nash (Grant Co.) downstream to the confluence with the Chikaskia River in Kay Co. I did not find the species at the downstream-most site S of Ponca City (Noble Co.).

There are records of M. hyostoma, but not M. tetranema, from the Chikaskia River, a northern tributary of the Salt Fork River, in Kay Co., Oklahoma. A recent (1994) collection of a single specimen (OSUS 27509) by J. Pigg from near the town of Blackwell indicates that a sparse population of M. hyostoma occurs in the lower Chikaskia River. However, the species apparently has always been rare in the drainage. Moore and Buck (1953) only collected one specimen in their survey of the river, and I found no specimens in 70 visits to 39 sites on the Chikaskia River mainstem and tributaries from south-central Kansas to its confluence with the Salt Fork River in north-central Oklahoma.

Cimarron River drainage

*Macrhybopsis tetranema* formerly inhabited the Cimarron River in southwestern Kansas. There are no records of *M. hyostoma* from this region. *Macrhybopsis tetranema* is known from one mainstem collection (UMMZ 161988; 6 specimens) in 1951 and three collections from Crooked Creek (UMMZ 160418, 176842, and 176849; 13 specimens) in 1950 and 1952. Notably, *M. tetranema* was absent in collections from Crooked Creek in 1941, 1942, 1958, and thereafter, and in the Kansas portions of the Cimarron River mainstem in 1955 and thereafter (F. B. Cross et al., in litt.; Larson, 1991; V. Tabor, pers. comm.). Thus, *M. tetranema* may never have been common in the Cimarron River drainage of Kansas. My 1993 collections at two sites on the Cimarron River mainstem and one site on Crooked Creek did not contain the species.

In Oklahoma, *M. tetranema* was known from the Cimarron River in northwest Harper Co. (OKMNH 32444; 4 specimens) downstream to the confluence with the Arkansas River in Pawnee Co. (OKMNH 39025; 2 specimens). Historically, *M. tetranema* was more widespread and abundant in the Cimarron River drainage than *M. hyostoma*. Between 1928 and 1965, 449 specimens of *M. tetranema* were taken in 22 collections of the species from the Cimarron River mainstem and 171 specimens were taken in seven collections of the species from tributaries of the river. During this period there were only three collections (19 specimens) of *M. hyostoma* from the Cimarron River, all from mainstem sites. All collections containing *M. hyostoma* also contained *M. tetranema*; thus, the two species were syntopic in the middle and lower Cimarron River.

For the period of 1976 through 1992, I found records of more than 400 collections from the Cimarron River drainage that failed to produce speckled chub (Luttrell, 1997; references therein); these included 17 samples of my own from the mainstem and tributaries (Table I and Appendix B). Both species may have been extirpated from the drainage by drought, possibly in 1965-1966 or 1970-1972 (Luttrell, 1997).

In the early 1990s *M. hyostoma* recolonized the Cimarron River, possibly as a result of dispersal from the Arkansas River via Keystone Reservoir (Luttrell, 1997). At present, *M. hyostoma* occupies all of its former range in the Cimarron River (Luttrell, 1997). *Macrhybopsis tetranema* remains absent from the Cimarron River drainage; intensive sampling since 1976 (Pigg, 1988; Luttrell, 1997; references therein) has not yielded any specimens of the species.

Canadian River drainage

Records of *M. tetranema* exist from the Beaver and North Canadian rivers and Coldwater and Palo Duro creeks in Texas, Harper, and Woodward counties of western Oklahoma. There are no records of *M. tetranema* from the North Canadian River downstream of Woodward Co., possibly due to a lack of sampling. In this study, I sampled eight sites encompassing the Beaver and North Canadian River mainstems, Palo Duro Creek, and Kiowa Creek, without finding speckled chub. I was unable to find water at historical collection localities on Coldwater Creek and the North Canadian River N of Guymon in 1992 and 1993. Jimmie Pigg, who has sampled the Beaver and North Canadian rivers intensively since 1976 (Pigg et al., 1992), captured a single specimen of *M. tetranema* from near Woodward in 1982 (OSUS 19235). The species was collected from this area in 1949, and, except for the 1982 record (possibly a bait-introduction), no subsequent collections (Larson, 1991; Pigg, unpubl. data; Appendix A) have contained the species. Extirpation of *M. tetranema* from the North Canadian River drainage in western Oklahoma appears related to a dramatic increase in irrigation wells and associated streamflow reductions since 1963 (see Wahl and Wahl, 1988).

Historically, *M. tetranema* inhabited the South Canadian River mainstem from the mouth of Ute Creek in northeastern

New Mexico downstream to south-central Oklahoma (near Purcell, Cleveland Co.). The species remains abundant from Ute Dam (Quay Co., New Mexico) downstream to Sanford Dam which now forms Meredith Reservoir (Hutchinson Co., Texas); collections from this area in 1976 (TU 99165) and 1990 (OSUS 18837) yielded more than 100 specimens. I made three collections at two sites in this region in 1995 and 1996 and collected 87 specimens of M. tetranema.

Only seven collections (1928-1959) of M. tetranema have been made from the South Canadian River between Lake Meredith and Purcell, Oklahoma, none of which contained more than 17 specimens. I made 10 visits to seven sites in this area without finding M. tetranema. Similarly, numerous collections by Larson (1991) and Pigg (unpubl. data) did not contain the species. Disappearance of M. tetranema between Sanford Dam and Purcell (sometime after 1959), parallels completion of Sanford Dam in 1965. The historically low abundance of M. tetranema in this stream reach and an apparent lack of the pea-sized gravel substrata preferred by speckled chubs (Luttrell, 1997) suggest the species may have been maintained by dispersal from upstream. Sanford Dam has not released any water since its completion in 1965, which precludes downstream dispersal of M. tetranema into the eastern Texas Panhandle and Oklahoma.

Before completion of Eufaula Reservoir in east-central

Oklahoma in 1964, *M. hyostoma* was known from the North Canadian River in McIntosh Co. (three collections; 26 specimens), the South Canadian River in Hughes, Pittsburg, and McIntosh counties (four collections; 16 specimens), and the Deep Fork River in Okmulgee and McIntosh counties (two collections; 3 specimens). Apparently, the species was more common (OKMNH 36223; 42 specimens) downstream from the confluence of these streams in an area now inundated by Eufaula Reservoir (McIntosh/Pittsburg Co.). In this study, I failed to find *M. hyostoma* in three formerly occupied stream reaches in the Canadian River drainage, sampled as follows: 1) four sites on the North Canadian River between Harrah (Oklahoma Co.) and Lake Eufaula; 2) four sites on the South Canadian River between Lexington (Cleveland Co.) and Lake Eufaula; and 3) seven sites on the Deep Fork River in Lincoln, Creek, and Okmulgee counties. Larson (1991) made 10 collections from these stream reaches, none of which contained speckled chub. Since 1992, only two specimens of *M. hyostoma* have been taken upstream of Eufaula Reservoir; these consisted of one specimen in each of two separate collections made by J. Pigg (unpubl. data) in the South Canadian River near Calvin (Hughes Co.). These collections suggest a residual population of the species may persist near Eufaula Reservoir; however, they may also represent incidental bait-bucket introductions.

Downstream of Eufaula Reservoir, I collected 10 M. hyostoma from the Canadian River near Whitefield (Haskell/Muskogee Co.) in 1993. Dispersal of individuals from this stream reach may explain the previously mentioned records (one specimen each) of the species in the lower Illinois River and the Arkansas River mainstem between Robert S. Kerr Lock and Dam and the Oklahoma-Arkansas border.

## Extirpations and Artificial Impoundments

Since 1939, 12 flood-control reservoirs and 17 lock and dam structures (McClellan-Kerr Navigation System) have been constructed (Moody et al., 1985) on streams within the historical range of speckled chub in the Arkansas River Basin. Figure 4 demonstrates a striking similarity in the temporal pattern of cumulative number of reservoirs and the cumulative number of extirpations of the two species of speckled chubs in the Arkansas River Basin. Thus, the period of extirpations (1940s through the 1970s) approximates the period of reservoir construction.

Table II and III and Figure 5 compare, for both species of speckled chub, approximate time of extirpation from segments of the Arkansas River Basin with time-of-completion for reservoirs that would have prevented recolonization from an existing population. The correlation was significant for *M. hyostoma* (Pearson's product-moment correlation, $n = 6$, $r = 0.89$, $P = 0.02$). The correlation for *M. tetranema* was not significant, either when two extirpations (Ute Creek, New Mexico and Arkansas River in Colorado) were excluded ($n = 5$, $r = 0.21$, $P = 0.73$) or when those two were kept in the analysis ($n = 7$, $r = 0.30$, $P = 0.51$). The correlation for both species combined was nearly significant, both when the two poorly sampled areas were excluded ($n = 10$, $r = 0.58$, $P = 0.08$) and when they were retained ($n = 12$, $r = 0.53$, $P = 0.08$).

## DISCUSSION

The record of collections for the Arkansas River Basin demonstrates that, during the past several decades, the distributions of both species of speckled chub have declined markedly. *Macrhybopsis tetranema* has been extirpated from approximately 90% of its historic range in the Arkansas River Basin. This species, which is endemic to the basin, persists only in two widely disjunct areas, the Ninnescah and lower Arkansas rivers in Kansas (about 100 river-km) and the South Canadian River between Ute and Meredith reservoirs in New Mexico and Texas (about 200 river-km). *Macrhybopsis hyostoma*, which is widespread in the Mississippi River

System, has been extirpated from about 55% of its former range in the Arkansas River Basin. The species still occurs in about 600 river-kilometers that include the Arkansas River mainstem and downstream reaches of major tributaries (Salt Fork, Cimarron, and Canadian rivers) between Kaw Reservoir and the McClellan-Kerr Navigation System.

The temporal pattern of extirpations of speckled chubs from the Arkansas River Basin closely coincides with that for reservoir construction. As discussed above, reservoirs have multiple effects that potentially contribute to the decline of native organisms adapted to stream conditions. Perhaps the most obvious effects are loss of habitat through inundation of the flowing-water environment and de-watering as a result of impoundment and diversion of water out of the stream-bed. None of the four declining prairie-fishes in the Arkansas River Basin (two speckled chubs, Arkansas River shiner, plains minnow) occurs to any significant degree in reservoirs. De-watering is particularly important in western, arid portions of the Arkansas River Basin, where, in part because of reservoir construction, streams that once had continual flow now have long periods of no flow or complete de-watering (Wahl and Wahl, 1988). For example, Pueblo and John Martin reservoirs and associated irrigation diversions have contributed to seasonal de-watering of the Arkansas River from the Colorado-Kansas border to near Great

Bend (Barton Co., Kansas) accounting for the extirpation of *M. tetranema* in this region (Cross and Moss, 1987).

A more subtle, and less substantiated, effect of reservoirs is the potential for increased levels of predation and competition as a result of changes in fish-assemblage structure both upstream and downstream of reservoirs (Echelle and Schnell, 1976; Cross and Moss, 1987). Cross and Moss (1987) noted that, possibly due to reservoirs, sight-feeding fishes were more abundant in prairie streams of western Kansas than they were historically. In the Arkansas River Basin of Oklahoma, the abundance and distribution of inland silversides, *Menidia beryllina*, have increased markedly since 1964, when it was first taken from the basin (Sisk and Stephens, 1964). This expansion may be a result of reservoir construction, as foretold by Sisk and Stephens (1964), who noted that reservoir construction favored increased abundance of this species. *Menidia beryllina* is a small, sight-feeding planktivore (Saunders, 1959) known to eat fish eggs (Bettoli et al., 1991). In rivers, *M. beryllina* occurs primarily in the main channel; thus, it may be an important factor in the decline of fishes like speckled chubs whose eggs and larvae drift suspended in the water column as they develop.

Finally, by acting as barriers to dispersal, reservoirs contribute to extirpation of local populations by blocking post-extirpation recolonizations. This factor explains absence of speckled chub and other prairie-stream fishes in a portion of the Red River Basin in Oklahoma (Winston et al., 1991), and it apparently explains the 20-year hiatus between the disappearance of *M. hyostoma* from the Cimarron River and its reappearance in the early 1990s (Luttrell, 1997). Bestgen and Platania (1991) invoked barriers to dispersal as a factor in the decline of *Hybognathus amarus* in New Mexico and Texas, and Etnier et al. (1979) attributed decline of *Hybognathus nuchalis* in Tennessee to habitat fragmentation as a result of reservoir construction.

Although extirpations of speckled chubs generally occurred during the period of reservoir construction in Oklahoma, the results indicate that, during this period, extirpation of individual populations of *M. tetranema* was not closely associated with year-of-completion for reservoirs that would have blocked dispersal from the nearest surviving population. This lack of association is expected from the metapopulation model, in which reservoirs would contribute to extirpation by disrupting the extinction/recolonization dynamic among local populations. In this hypothesis, time of reservoir construction does not necessarily correspond with time of extirpation because extirpation results from factors other than reservoir construction. For example, *M. tetranema* persisted in the upper Salt Fork of the Arkansas River for more than 20 years after construction of Great Salt Plains Reservoir and then was extirpated, probably as a result of a drought (Luttrell, 1997). Similarly, a population has persisted for more than 30 years between Ute Reservoir in New Mexico and Meredith Reservoir in the Texas Panhandle. This appears to be the largest extant population of *M. tetranema*, possibly because, as suggested for Arkansas River shiner in this area (Larson, 1991), pulses in river discharge remain adequate for reproduction due to frequent midsummer rains and the pronounced topographic relief.

In contrast with the results for *M. tetranema*, local extirpations of *M. hyostoma* during the period of reservoir construction were significantly correlated with year-of-completion for reservoirs blocking recolonization. This correlation is predicted from the hypothesis that extirpations were primarily a result of a disrupted system of source/sink populations. Under this model, reservoir construction would be followed shortly by extirpation of populations dependent on dispersal for their persistence.

The following observations suggest that disrupted source/sink dynamics applies to at least three of the six extirpations listed in Table III for *M. hyostoma*; i.e. those for the North Canadian, South Canadian, and Deep Fork rivers upstream of the present Eufaula Reservoir: 1) the last collections of the species from these rivers were between 1962 and 1965, and the reservoir was completed in 1964; 2) the species was historically sparse in these streams (Luttrell, 1997); and 3) an analysis of habitat characteristics in the North and South Canadian rivers suggested that, presently at least, habitats are suboptimal for the species because of a lack of suitable substrata (Luttrell, 1997). On the other hand, disruption of the extinction/recolonization dynamic for the metapopulation apparently explains the history of records for *M. hyostoma* in the Cimarron River (Luttrell, 1997). The species disappeared from that river by the early 1970s, possibly as a result of drought conditions in the late 1960s, and, despite intensive collecting effort, did not reappear in collections until 1992. By 1994 the species had re-invaded most of its historic range in the river. Thus, habitat conditions in the Cimarron River seem adequate to support the species. The presence of Keystone Reservoir on the former confluence of the Cimarron and Arkansas rivers apparently retarded the rate of recolonization. However, the species persisted in the Arkansas River, between Kaw and Keystone reservoirs, during its approximate 20-year absence from the Cimarron River.

In conclusion, both species of speckled chub have declined markedly in the Arkansas River Basin. Initial causes of local extirpation often cannot be assigned with certainty. However, regardless of such causes, the presence of reservoirs and other barriers to dispersal (e.g., areas of dry stream-bed) threaten the two species with continued incremental decline through time. Both species need continued monitoring of their status. Such monitoring is particularly important for *M. tetranema*, which is endemic to the basin and consists of two widely disjunct, restricted populations. Furthermore, managers should consider reintroducing *M. tetranema* into some areas of former occurrence, such as the Cimarron River and the upper Salt Fork of the Arkansas River.

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Table I. Summary of sampling in this study and historical and present status of *M. hyostoma* and *M. tetranema* in the Arkansas River Basin. Collecting effort for this study is shown as number of sites sampled and (in parenthesis) number of visits. Historical = pre-1991 collections; Current = collections since 1991; shown are are number of collections and (in parenthesis) number of specimens; *nc* = no collections in this study; *nr* = no known record(s). Historical records appear in Appendix A. Specific locality information for sites sampled in this study are in Appendix B.

| Stream:<br>Reach | Collecting effort | *M. hyostoma*<br>Historical | *M. hyostoma*<br>Present | *M. tetranema*<br>Historical | *M. tetranema*<br>Present |
|---|---|---|---|---|---|
| Arkansas River Mainstem: | | | | | |
| A. John Martin Dam (CO) to Wichita (KS) | 6 (6) | *nr* | *nr* | 5 (18) | *nr* |
| B. Wichita (KS) to Kaw Reservoir (OK) | 4 (8) | 4 (15) | *nr* | 7 (38) | 3 (17) |
| C. Kaw to Keystone Reservoir | 6 (8) | 22 (351) | 4 (151) | 1 (1) | *nr* |
| D. Keystone Reservoir to Haskell | 3 (3) | 6 (20) | 2 (9) | *nr* | *nr* |
| E. Muskogee to OK-AR border | *nc* | 2 (43) | 2 (2) | *nr* | *nr* |
| F. Arkansas | *nc* | 10 (343) | *nr* | *nr* | *nr* |
| Minor Tributaries: | | | | | |
| Red Rock Creek NW of Perry (OK) | 1 (1) | 1 (1) | *nr* | *nr* | *nr* |
| Salt Creek near Fairfax (OK) | *nc* | 1 (1) | *nr* | *nr* | *nr* |
| Ninnescah River (KS): | | | | | |
| A. North Fork mainstem | 2 (2) | *nr* | *nr* | 2 (120) | *nr* |
| B. South Fork mainstem | 5 (10) | *nr* | *nr* | 1 (24) | 2 (16) |
| C. Lower Ninnescah mainstem | 2 (2) | 1 (1) | *nr* | 1 (1) | *nr* |
| Salt Fork of the Arkansas River drainage:<br>Chikaskia River: | | | | | |
| A. Mainstem and tributaries (KS and OK) upstream of Blackwell (OK) | 33 (61) | *nr* | *nr* | *nr* | *nr* |

Table I. (continued).

| Stream: Reach | Collecting effort | *M. hyostoma* Historical | *M. hyostoma* Present | *M. tetranema* Historical | *M. tetranema* Present |
|---|---|---|---|---|---|
| Salt Fork of the Arkansas River drainage: | | | | | |
| Chikaskia River: | | | | | |
| B. Blackwell to confluence with Salt Fork of the Arkansas R. | 6 (9) | 9 (36) | 1 (1) | nr | nr |
| Medicine Lodge River: | | | | | |
| A. KS mainstem | 6 (19) | nr | nr | 4 (19) | nr |
| B. OK mainstem | 2 (4) | nr | nr | nr | nr |
| Kansas tributaries: | | | | | |
| Elm Creek | 1 (1) | nr | nr | 1 (3) | nr |
| Salt Fork of the Arkansas River: | | | | | |
| A. KS mainstem | 3 (3) | nr | nr | nr | nr |
| B. KS-OK border to Great Salt Plains Reservoir | 7 (14) | nr | nr | 2 (42) | nr |
| C. Great Salt Plains to mouth | 11 (19) | 16 (386) | 7 (35) | 1 (11) | nr |
| Minor Tributaries: | | | | | |
| Mule Creek (KS) | 2 (3) | nr | nr | 2 (10) | nr |
| Nescatunga Creek (KS) | 1 (2) | nr | nr | nr | nr |
| Sandy Creek (OK) | 2 (2) | nr | nr | nr | nr |
| Pond near Cherokee (OK) | nc | nr | nr | 1 (3) | nr |
| Cimarron River: | | | | | |
| A. KS mainstem | 2 (2) | nr | nr | 1 (6) | nr |

Table I. (continued).

| Stream: Reach | Collecting effort | M. hyostoma Historical | M. hyostoma Present | M. tetranema Historical | M. tetranema Present |
|---|---|---|---|---|---|
| Cimarron River: | | | | | |
| B. Mainstem in N Beaver and NW Harper Co., OK | nc | nr | nr | 1 (4) | nr |
| C. Mainstem from KS-OK border NNW of Buffalo (OK) to Orienta | 3 (6) | nr | 1 (90) | 2 (44) | nr |
| D. Orienta to Guthrie | 7 (17) | 1 (1) | 10 (181) | 1 (5) | nr |
| E. Guthrie to Ripley | 4 (11) | 1 (8) | 6 (55) | 15 (337) | nr |
| F. Ripley to Keystone Reservoir | 4 (5) | 1 (10) | 4 (17) | 3 (59) | nr |
| Minor Tributaries: | | | | | |
| Crooked Creek (KS) | 1 (1) | nr | nr | 3 (13) | nr |
| Eagle Chief Creek (OK) | 1 (2) | nr | nr | 3 (146) | nr |
| Main Creek (OK) | nc | nr | nr | 1 (2) | nr |
| Misc. tributaries (OK) | 12 (31) | nr | nr | nr | nr |
| Skeleton Creek (OK) | 1 (1) | nr | nr | 1 (7) | nr |
| Lower Stillwater Creek (OK) | 3 (5) | nr | nr | 1 (12) | nr |
| Upper Stillwater Creek (OK) | 7 (19) | nr | nr | nr | nr |
| Wild Horse Creek (OK) | 2 (3) | nr | nr | 1 (4) | nr |
| Canadian River drainage: Canadian River (OK): | | | | | |
| A. Lake Eufaula (pre-construction) | nc | 3 (56) | nr | nr | nr |
| B. Eufaula Dam (OK) to confluence with Arkansas River | 1 (1) | 3 (23) | 1 (10) | nr | nr |
| Deep Fork River (OK): | | | | | |
| A. Lincoln Co. mainstem | 4 (4) | nr | nr | nr | nr |

Table I. (continued).

| Stream: Reach | Collecting effort | *M. hyostoma* Historical | *M. hyostoma* Present | *M. tetranema* Historical | *M. tetranema* Present |
|---|---|---|---|---|---|
| Deep Fork River (OK): | | | | | |
| B. Okmulgee Co. mainstem | 2 (2) | nr | nr | nr | nr |
| C. McIntosh Co. mainstem | nc | 2 (3) | nr | nr | nr |
| Minor Tributaries: | | | | | |
| Little Deep Fork R. (Creek Co.) | 1 (1) | nr | nr | nr | nr |
| North Canadian River (OK): | | | | | |
| A. Beaver River mainstem | 3 (3) | nr | nr | 1 (1) | nr |
| North Canadian River (OK): | | | | | |
| B. North Canadian River mainstem upstream of Woodward | nc | nr | nr | 1 (16) | nr |
| C. Woodward to Harrah | 7 (8) | nr | nr | 2 (52) | nr |
| D. Harrah to Lake Eufaula | 4 (4) | 3 (26) | nr | nr | nr |
| Western tributaries (OK): | | | | | |
| Coldwater Creek | nc | nr | nr | 1 (18) | nr |
| Kiowa Creek | 1 (1) | nr | nr | nr | nr |
| Palo Duro Creek | 1 (1) | nr | nr | 1 (6) | nr |
| South Canadian River: | | | | | |
| A. Ute Reservoir (NM) to Meredith Reservoir (TX) | 2 (3) | nr | nr | 7 (351) | 3 (87) |
| B. Meredith Reservoir to Lexington (OK) | 7 (10) | nr | nr | 7 (46) | nr |

Table I. (concluded).

| Stream: Reach | Collecting effort | *M. hyostoma* Historical | *M. hyostoma* Present | *M. tetranema* Historical | *M. tetranema* Present |
|---|---|---|---|---|---|
| South Canadian River: | | | | | |
| C. Lexington to Lake Eufaula: | 4 (5) | 4 (16) | 2 (2) | nr | nr |
| Minor Tributaries (NM): | | | | | |
| Revuelto Creek: | nc | nr | nr | 1 (4) | nr |
| Illinois River (OK): | | | | | |
| A. Mainstem near mouth | nc | 1 (7) | 1 (1) | nr | nr |

Table II. Last record of extirpated populations of *M. tetranema*, and year-of-completion for reservoirs that isolated areas of extirpation from a source of immigrants.

| Species/ Stream segment | Year of last record (Museum No.) | Associated reservoir | Year of completion |
|---|---|---|---|
| 1. Arkansas R., Colorado | 1889[1] | John Martin | 1948 |
| 2. Ute Cr., New Mexico | 1939[2] | Ute | 1963 |
| 3. Arkansas R. upstream of Wichita, Kansas | 1958 (KU 3938) | Loss of habitat[3] | -- |
| 4. S. Canadian R. downstream of Meredith Reservoir, Texas | 1959 (TU 20140) | Meredith | 1965 |
| 5. Arkansas R. between Kaw and Keystone reservoirs, Oklahoma | 1960 (OKMNH 39032) | Kaw | 1976 |
| 6. Salt Fork R. upstream of Great Salt Plains Reservoir, Kansas and Oklahoma | 1964 (KU 8574) | Great Salt Plains | 1941 |
| 7. Cimarron R., Kansas and Oklahoma | 1965 (OKMNH 33985) | Keystone | 1964 |
| 8. N. Canadian R. upstream of Canton Reservoir, Oklahoma | 1949 (OSUS 4124)[4] | Canton | 1948 |

[1]Record from Jordan (1891); status of specimens unknown.
[2]Record from Sublette et al. (1990); status of specimens unknown.
[3]Stream-bed de-watered much of the year by ground- and surface-water usage for irrigation (F. B. Cross et al., in litt.).
[4]Collection of a single specimen in 1982 (OSUS 19235), 34 years after the next previous collection, probably represents a transient anthropogenic introduction, possibly by the bait industry.

Table III. Last record of extirpated populations of M. hyostoma, and year-of-completion for reservoirs that isolated areas of extirpation from a source of immigrants.

| Species/ Stream segment | Year of last record (Museum No.) | Associated reservoir | Year of completion |
|---|---|---|---|
| 1. N. Canadian R., OK | 1962 (OKMNH 35090) | Eufaula | 1964 |
| 2. Deep Fork R., OK | 1962 (OKMNH 36211) | Eufaula | 1964 |
| 3. Arkansas R., AR | 1963 (OSUS 7224) | Ozark Lock and Dam | 1969 |
| 4. S. Canadian R., OK | 1965[1] (KU 5952) | Eufaula | 1964 |
| 5. Cimarron R., OK | 1965[2] (OKMNH 33985) | Keystone | 1964 |
| 6. Arkansas R., KS | 1984 (KU 21704) | Kaw | 1976 |

[1]Collection of single specimens in two separate collections since 1992 appear to represent recent anthropogenic introductions, see text for discussion.
[2]Prior to re-invasion by the species in the early 1990s; see text and Luttrell (1997).

Fig. 1. Historical distribution of speckled chub in the Arkansas River Basin (1884-1990). C = Chikaskia River; D = Deep Fork River; M = Medicine Lodge River; N = Ninnescah River; S = Salt Fork of the Arkansas River. Shaded circles = records of *M. tetranema*; black circles = records of *M. hyostoma*; squares = records of both species. Inset depicts the approximate combined range of both species in the drainage.

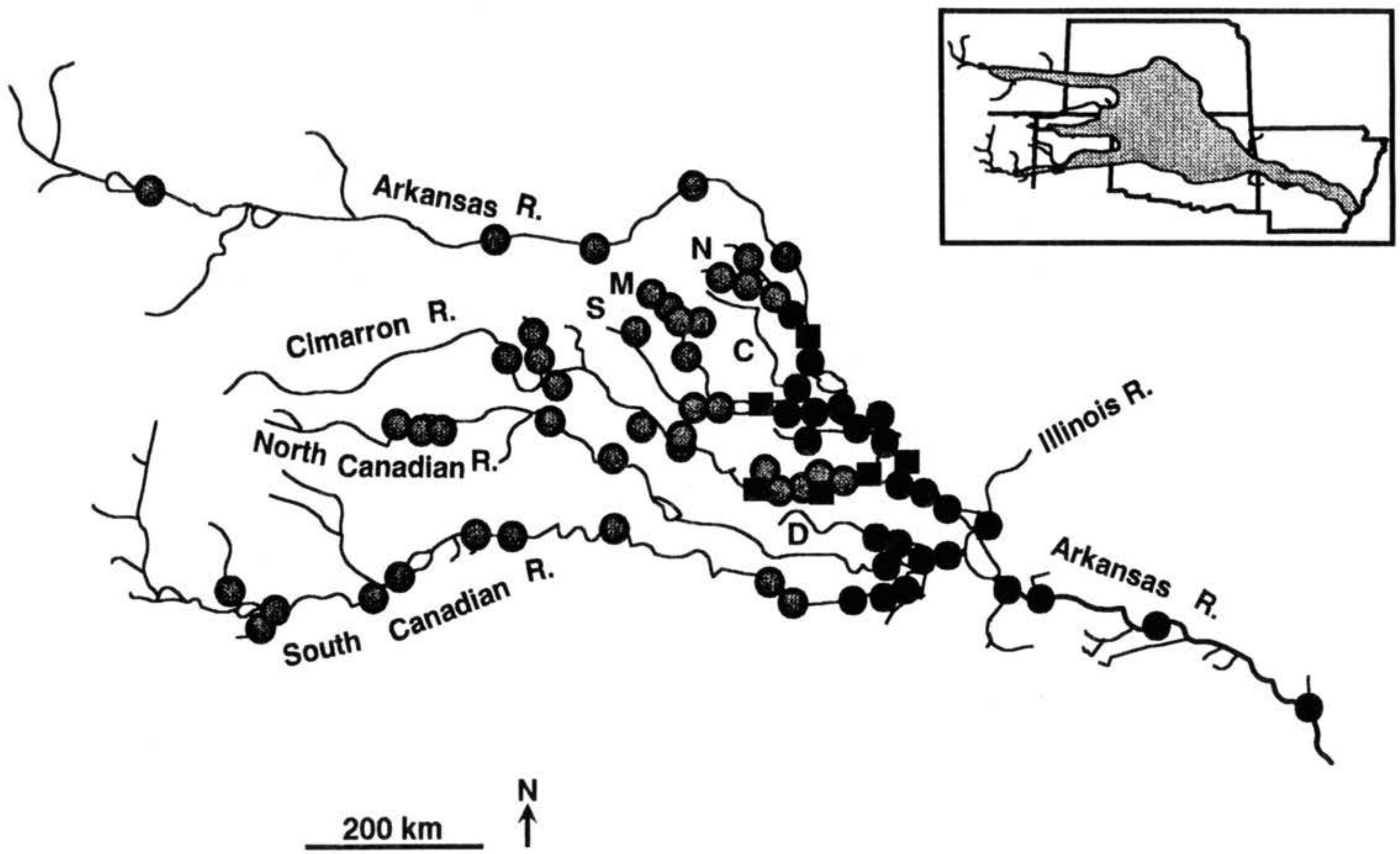

Arkansas R.
N
M
S
C
Cimarron R.
North Canadian R.
D
Illinois R.
Arkansas R.
South Canadian R.
200 km
N

Fig. 2. Present distribution of speckled chub in the Arkansas River Basin (1991-1996). Shown are 12 flood-control reservoirs within stream reaches historically occupied by speckled chub. Webbers Falls, Robert S. Kerr, and Dardanelle reservoirs and other lock and dam structures within the McClellan-Kerr Navigation System are not shown. GSPR = Great Salt Plains Reservoir; shaded circles = records of *M. tetranema*; black circles = records of *M. hyostoma*.

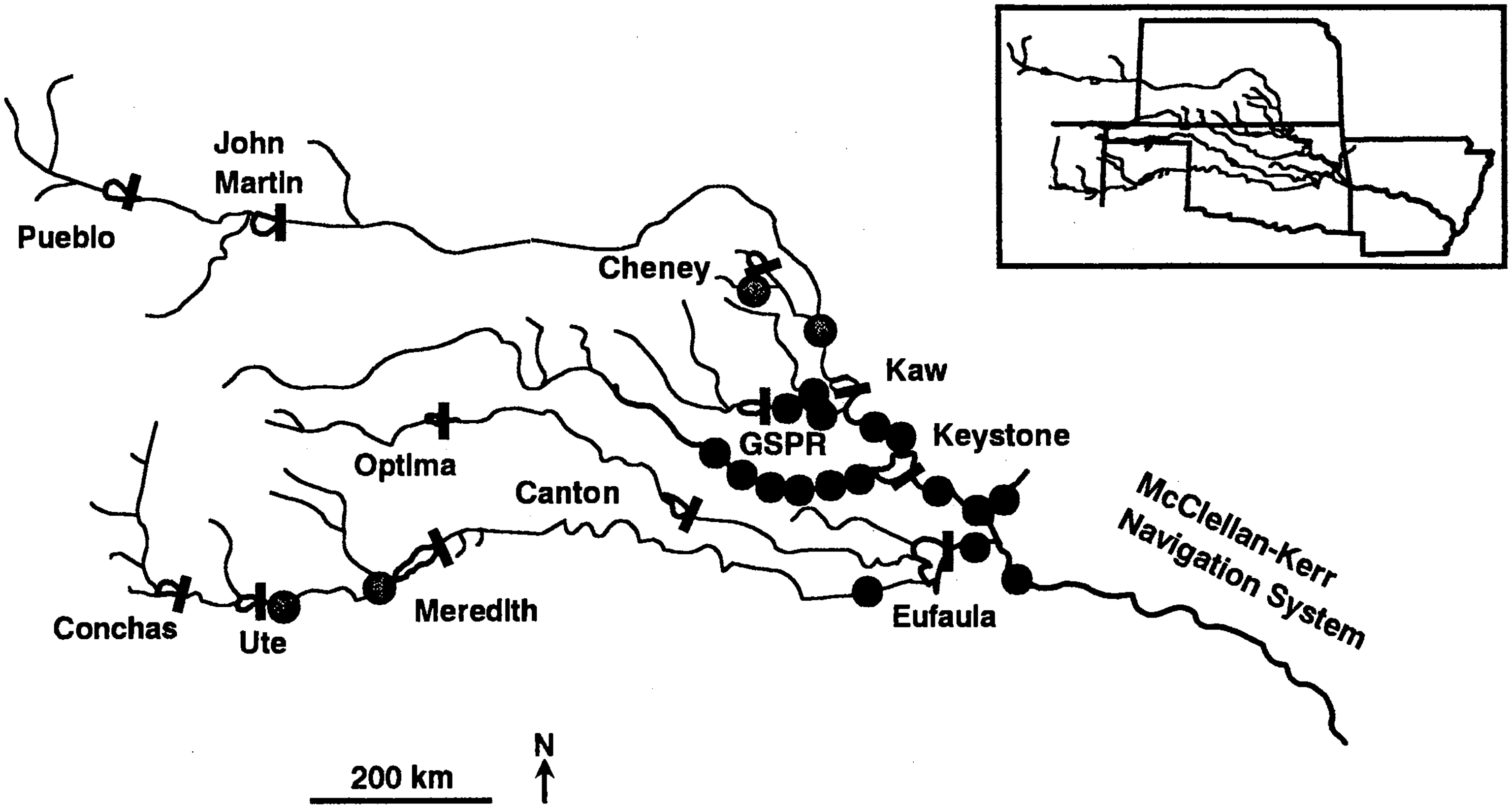

John
Martin
Pueblo
Cheney
Kaw
GSPR
Keystone
Optima
Canton
McClellan-Kerr
Navigation System
Meredith
Eufaula
Conchas
Ute
200 km
N

Fig. 3. Mean daily discharge for the Salt Fork of the Arkansas River near Jet, Oklahoma. Plotted data are maximum mean daily flows for May-August of 1958-1969. Black circles = years when May-August flows never exceeded 1,000 CFS.

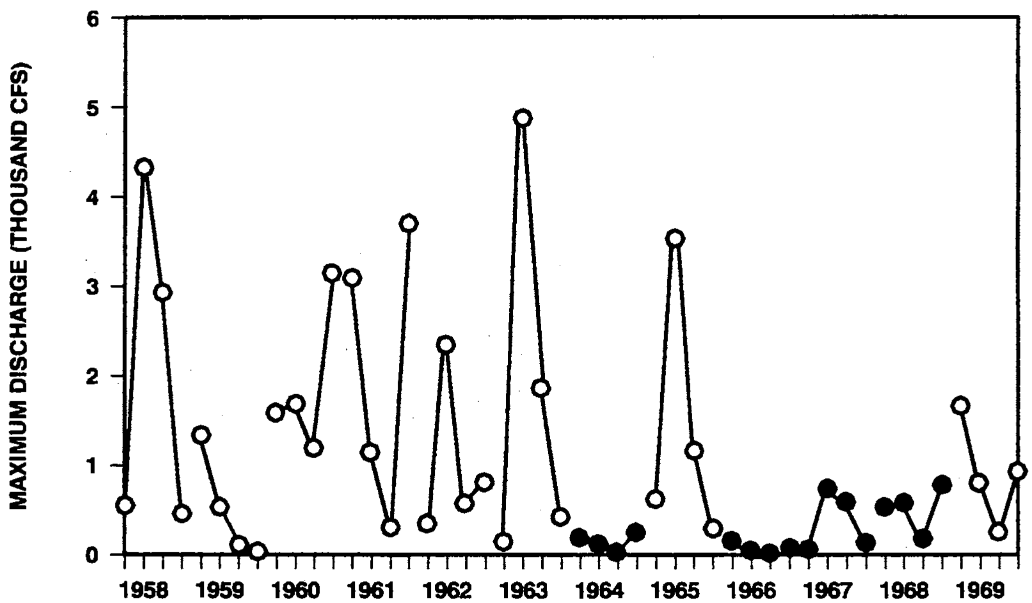
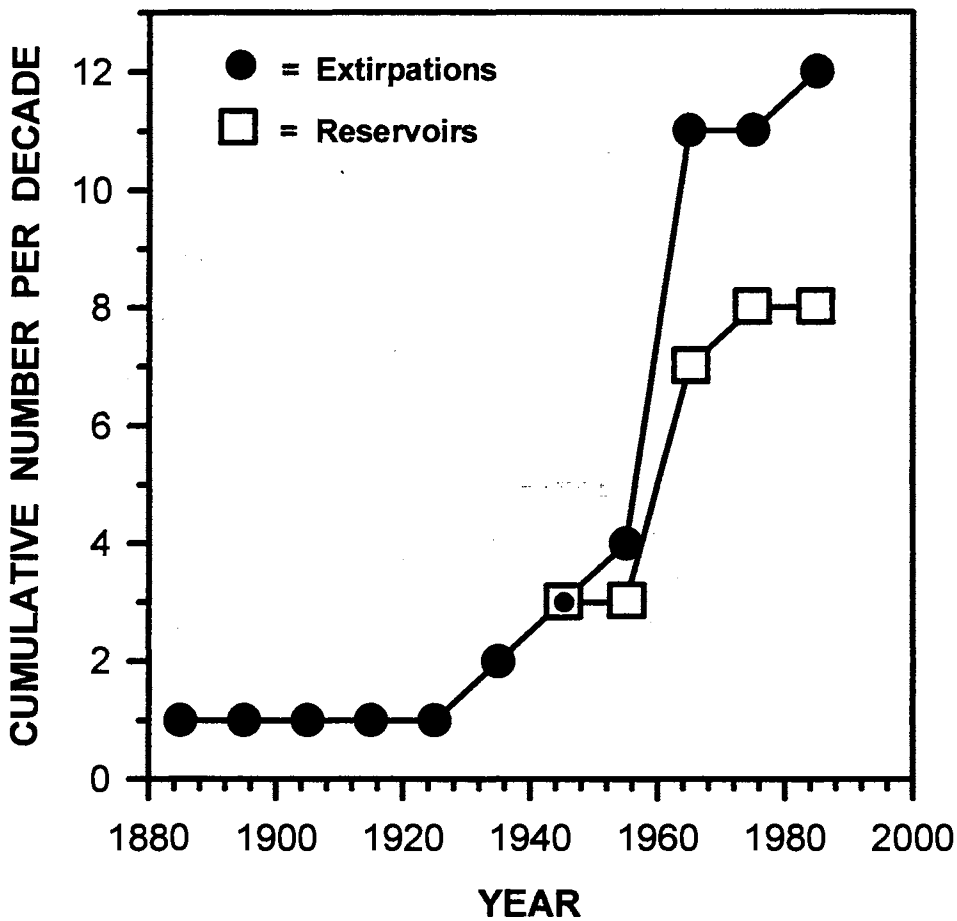
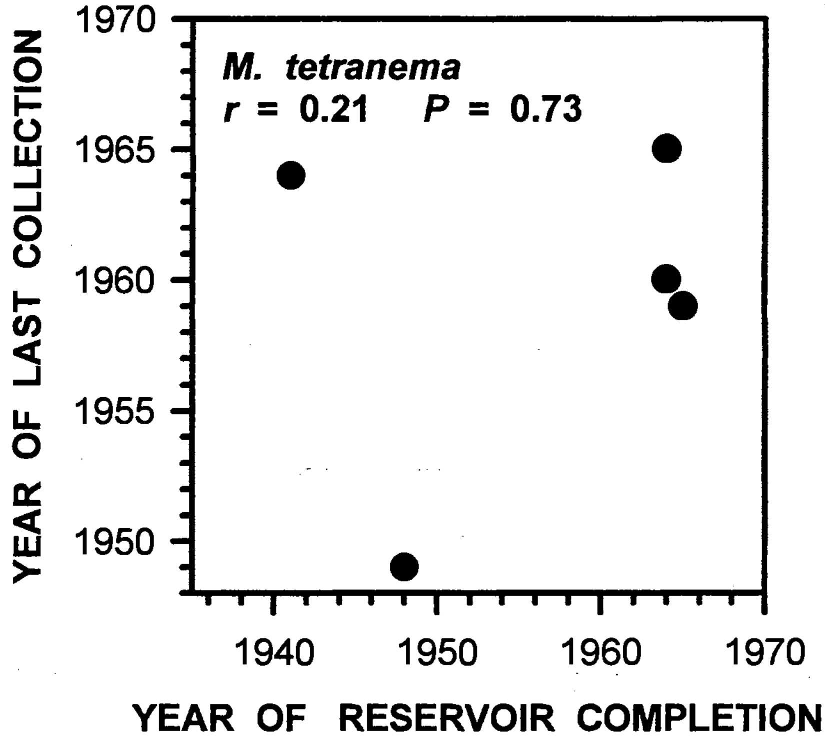

MAXIMUM DISCHARGE (THOUSAND CFS)
0
1
2
3
4
5
6
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969

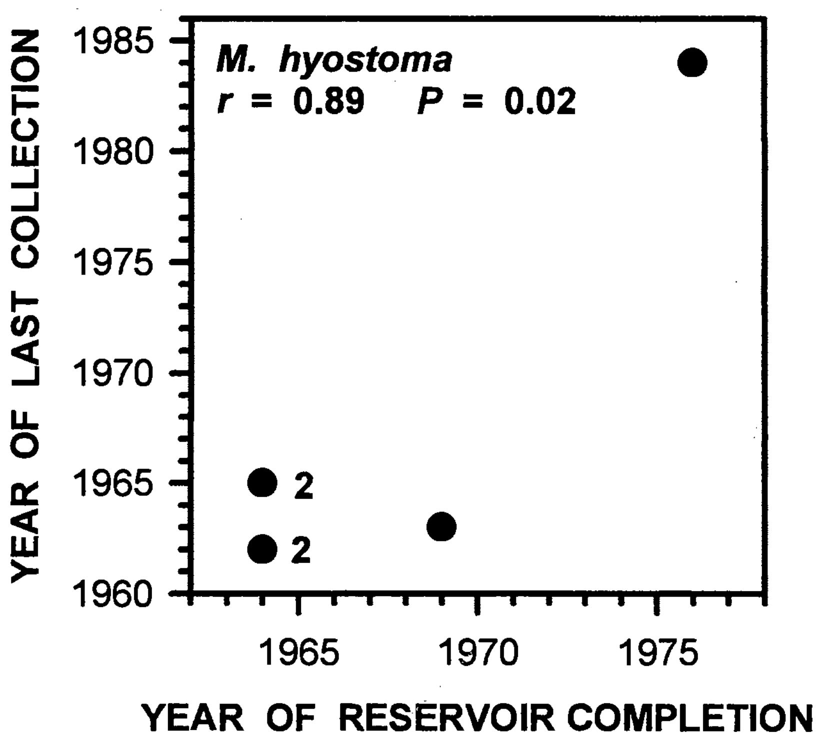
Fig. 4. Temporal cumulative relationship between extirpations of *M. tetranema* and *M. hyostoma* from stream reaches and completion of adjacent reservoirs in the Arkansas River drainage.



= Extirpations
= Reservoirs
CUMULATIVE NUMBER PER DECADE
0
2
4
6
8
10
12
1880
1900
1920
1940
1960
1980
2000
YEAR

Fig. 5. Comparison of approximate time of extirpation of *M. tetranema* (upper pane) and *M. hyostoma* (lower pane) with completion times of reservoirs that would have prevented recolonization from adjacent stream reaches in the Arkansas River drainage. *r*-values = Pearson product-moment correlation coefficients.


M. tetranema
r = 0.21 P = 0.73
YEAR OF LAST COLLECTION
1970
1965
1960
1955
1950
1940
1950
1960
1970
YEAR OF RESERVOIR COMPLETION


M. hyostoma
r = 0.89 P = 0.02
YEAR OF LAST COLLECTION
1985
1980
1975
1970
1965
1960
2
2
1965
1970
1975
YEAR OF RESERVOIR COMPLETION

# CHAPTER II

## HABITAT CHARACTERISTICS AND DISTRIBUTION OF SPECKLED CHUB (CYPRINIDAE: *MACRHYBOPSIS HYOSTOMA*) IN THE ARKANSAS RIVER BASIN

### INTRODUCTION

In this paper, I examine physical habitat characteristics associated with occurrence of *Macrhybopsis hyostoma* in tributaries of the Arkansas River Basin in Oklahoma. *Macrhybopsis hyostoma* is one of several taxa being elevated to species status as a result of D. Eisenhour's (pers. comm.) on-going morphological study of a widespread species complex previously referred to as *Macrhybopsis aestivalis*. Two members of the speckled chub complex occur in the Arkansas River Basin (D. Eisenhour, pers. comm.). These include *M. hyostoma* a species that is widespread in the Mississippi River System and historically occupied the Arkansas River mainstem and the lower reaches of its major western tributaries. The other species, *M. tetranema*, is endemic to the Arkansas River Basin, where it historically occupied upstream reaches of the major western tributaries. The two species formerly occurred together in the mid-reaches of these tributaries.

The distributions of both species of speckled chub in the Arkansas River Basin have declined in the past 20 years. Impoundment of the lower Arkansas River mainstem by the McClellan-Kerr Navigation System apparently eliminated _M. hyostoma_ from the basin in Arkansas (Robison and Buchanan, 1988). The species appears to be effectively extirpated from the North Canadian, South Canadian, and Deep Fork rivers upstream of Lake Eufaula in eastern Oklahoma (Luttrell, 1997). The other species, _M. tetranema_, apparently has been extirpated from most of its former range except for the South Canadian River in northeastern New Mexico and the Texas Panhandle and the Ninnescah and Arkansas rivers in Kansas (Luttrell, 1997). The decline of both species in the upper Arkansas River Basin may have resulted, in part, from altered streamflow regimes caused by irrigation practices and reservoir construction (Luttrell, 1997). Altered stream flows have been implicated in the decline of two other cyprinids (Arkansas River shiner _Notropis girardi_ and plains minnow _Hybognathus placitus_) from waters previously occupied by both species of speckled chub (Cross and Moss, 1987; Larson, 1991; Taylor and Miller, 1990; Echelle et. al., 1995).

Knowledge of speckled chub biology is based largely on anecdotal observations (Starrett, 1950a; Starrett, 1950b;

Starrett, 1951; Trautman, 1957; Cross, 1967; Miller and Robison, 1973; Pflieger, 1975; Becker, 1983). In Iowa, speckled chub live about 1.5 years (Starrett, 1951) and feed principally on larval Diptera (Starrett, 1950b). Bottrell et al. (1964) reported that speckled chub in the Cimarron River of Oklahoma depend on spring and summer spates to suspend their semi-buoyant eggs in the current until they hatch in 24 to 28 hours. Their results are likely attributable to M. tetranema, because M. hyostoma was rare in the Cimarron River during the 1960s (Luttrell, 1997).

My objective was to gain an understanding of the habitat requirements of M. hyostoma through an analysis of within-site habitat correlates of its occurrence. For additional insight, I then compared habitat conditions at sites of occurrence with two different situations where the species was absent: 1) upstream areas in the Salt Fork of the Arkansas River where M. hyostoma was historically absent, but which formerly supported a similar species (M. tetranema), and 2) areas of historical occurrence upstream of Lake Eufaula (North and South Canadian rivers) where M. hyostoma has been effectively extirpated. Since 1992, two collections of a single specimen each have been made from the South Canadian River near Calvin, just upstream of Lake Eufaula (J. Pigg, unpubl. data). These probably represent transient introductions, possibly as a result of bait transport.

## MATERIALS and METHODS

Attempts to collect *M. hyostoma* with seines (7.62-m x 1.8-m, 3.2-mm mesh) were made at 24 sites in the Arkansas River Basin from June through August 1994 and 1995 (Fig. 6). Six streams were sampled as follows: seven sites on the Cimarron River, three on the Medicine Lodge River, three on the North Canadian River, six on the South Canadian River, three on the Salt Fork of the Arkansas River upstream of Great Salt Plains Reservoir (upper Salt Fork River), and two on the Salt Fork of the Arkansas River downstream of Great Salt Plains Reservoir (lower Salt Fork River). Voucher specimens of speckled chub were deposited in the Oklahoma State University Collection of Vertebrates (OSUS).

### Habitat Measurements

At each site, 10 downstream seine-hauls, each covering 100 to 152 $m^2$, were made in, or adjacent to, the main channel within a 1.5- to 2.0-km stream reach. Sampling efforts began at the lower end of a stream reach and proceeded in an upstream direction to minimize disturbance and displacement of fish. For each seine-haul I measured the area ($m^2$) seined and, at five or six points, depth (cm), velocity (cm/s), substratum compaction (cm), and percent composition of seven substratum particle sizes. Measurements were made at the corners and center of seine-hauls with areas less than 150 $m^2$ (five points). Two measurements were made near the center when seine-haul area exceeded 150 $m^2$ (six points). For analysis, seine-hauls were characterized by the mean for each habitat variable.

A metered wading-rod (3-cm diameter) was used to measure depth and substratum compaction. For current velocity, the rod was field-calibrated with a Pygmy-Gurley current meter to approximate current velocity at 0.60 depth from the surface. Difference in water height (cm) on the upstream and downstream sides of the rod was converted to velocity in cm/s by applying the following regression equation ($\underline{n}$ = 60, $\underline{r}^2$ = 0.59, $\underline{P}$ < 0.01, Standard Error of Estimate = 0.085): Velocity in cm/s = 0.138386 + 0.068903 • difference in water height. Substratum compaction was measured as the distance the rod penetrated the substratum with a 10-kg force.

Substratum was assessed by scooping into the stream bottom with a wide-mouthed 470-ml jar until it was full, then covering the jar and raising it to the surface and pouring out the contents. The percent abundance of fines (<1 mm), small-sand (1-2 mm), coarse-sand (2-5 mm), and pea-sized gravel (5-9 mm) were then visually estimated based on a modified Wentworth classification (see Orth, 1983).

Percent abundances of pebble\cobble (9-250 mm), boulder ($\geq$ 250 mm), and bedrock were estimated from six hand-grab samples made within 0.75-$m^2$ of each point measurement.

Habitat-use observations on juvenile and adult speckled chub were combined for identification of habitat limitations because streams must contain suitable habitat for both stages in order to support a speckled chub population. Where juveniles and adults were treated separately, length-frequency histograms and the presence or absence of scale annuli were used to separate them. Scales from larger specimens occasionally exhibited two annuli, however, they were often the same size as other specimens with only one annulus, therefore I recognized two age-classes, juveniles (no annuli) and adults (one or more annuli). In summer samples, juveniles were typically $\leq$ 35 mm SL, whereas adults were $\geq$ 38 mm SL.

## Habitat Analyses

Habitat observations for juvenile and adult *M. hyostoma* from the Cimarron River (21 seine-hauls, six sites, 170 specimens) were pooled with those from the lower Salt Fork River (six seine-hauls, two sites, 29 specimens). No differences in habitat utilization by juvenile or adult speckled chub were detected between these streams (Kolmogorov-Smirnov two-sample test for each habitat variable; $\underline{P} > 0.05$). I did not test for habitat-variable interactions because determination of their biological meaning without more detailed speckled chub life history data is problematic.

Because data were pooled from several sites, habitat utilization is presented as preference distributions (habitat use / habitat availability) to correct for differences in habitat availability between sites. In this analysis, "habitat availability" refers to the proportionate abundance of habitat characteristics in seine-hauls taken from habitat situations that, based on prior experience (Luttrell, 1997) and the literature (e.g., Starrett, 1951; Trautman, 1957), were most likely to produce speckled chub. Preference distributions were constructed for depth, velocity, substratum compaction, fines, small-sand, coarse-sand, and pea-sized gravel. Multiple-zero values prevented analysis of preference distributions for pebble\cobble, boulder, and bedrock. The means of habitat variables within seine-hauls containing speckled chub were treated as habitat-use observations. Those seine-hauls, plus seine-hauls not containing the species (at sites where M. hyostoma was present) were treated as observations of habitat availability. Proportional habitat availability was calculated using seine-haul area.

The Kolmogorov-Smirnov two-sample test (Sokal and

Rohlf, 1981) was used to compare distributions of habitat utilization and habitat availability for depth, velocity, substratum compaction, fines, small-sand, coarse-sand, and pea-gravel substrata. A significant difference ($P < 0.05$) between distributions indicates non-random use of that habitat variable (i.e., selection). I utilized an electivity index (Jacobs, 1974) to identify selection for specific intervals within habitat variables. For each interval of a variable's distribution, the electivity (D) is $D = [r-p]\bullet[(r+p)-2rp]^{-1}$, where $r$ is the proportion of animals utilizing the interval and $p$ is proportional availability of that interval. This index varies from -1 to +1, and is interpreted as follows (Moyle and Baltz, 1985): -1.00 to -0.50, strong avoidance; -0.49 to -0.26, moderate avoidance; -0.25 to +0.25, neutral selection; +0.26 to +0.49, moderate selection; +0.50 to +1.00, strong selection. Selection for non-overlapping intervals of a habitat variable by juvenile and adult _M. hyostoma_ indicates segregation of age-classes on that variable. Innate preferences can only be determined under controlled conditions that make all states of a resource equally available. Nevertheless, potential preferences identified from field observations provide valuable insight into species preferences in nature (Baltz, 1990).

Habitat data from 80 seine-hauls at eight sites where

*M. hyostoma* still occurs: six on the Cimarron River (uppermost site excluded) and two on the lower Salt Fork River were used to construct a discriminant function model for prediction of speckled chub occurrence in individual seine-hauls. Discriminant-function groups were assigned as follows: 1) absent = 0 chubs, 2) rare = 1 to 4 chubs, and 3) common = 5 or more chubs. Habitat data from 160 seine-hauls at 16 sites where the species did not occur (either extirpated or not known to be present) were then classified with the computed function. These sites included the uppermost Cimarron River site and all sites sampled on the North Canadian, South Canadian, Medicine Lodge, and upper Salt Fork rivers (Fig. 6). Arcsin (percentage data) and natural log (all other data) transformations improved multivariate normality and homoscedasticity. Attempts to simplify the model by step-wise discriminant function analysis resulted in elevated classification error rates, thus the full model was retained to maximize predictability (SAS, 1985).

To describe possible habitat limitations to the distribution *M. hyostoma* at the stream level, habitat data for all seine-hauls were grouped by sites, and then placed into one of three categories: 1) chub present = six Cimarron River sites and two from the Salt Fork of the Arkansas River downstream of Great Salt Plains Reservoir (= lower Salt Fork River); 2) chub historically absent = the upstream-most Cimarron River site, three on the Medicine Lodge River, and three on the Salt Fork of the Arkansas River upstream of Great Salt Plains Reservoir (= upper Salt Fork River); and 3) chub effectively extirpated = six sites on the South Canadian River and three on the North Canadian River. Habitat data were either arcsin (percentage data) or natural log (all other data) transformed. I used analysis-of-variance (ANOVA; $\alpha = 0.01$) with hierarchically nested effects (i.e., seine-haul within site within stream within category) to account for within-category variation in testing among-category differences (Steel and Torrie, 1980; SAS, 1985). Multiple comparisons ($\alpha = 0.01$) were made with Tukey's HSD (SAS, 1985).

## RESULTS

I collected 199 speckled chub at six sites on the Cimarron River (170 chubs in 21 of 60 seine-hauls) and two sites on the lower Salt Fork River (29 chubs in 6 of 20 seine-hauls). None were collected at the 16 other study sites (Fig. 6). Of the 27 seine-hauls containing speckled chub, 13 contained juveniles ($\underline{n}$ = 30), 11 had adults ($\underline{n}$ = 131), and three contained both age-groups (28 juveniles and 5 adults). Juvenile speckled chub were non-randomly distributed (Kolmogorov-Smirnov two-sample test; $\underline{P} < 0.01$) over gradients of velocity, percent small-sand, percent coarse-sand, and percent pea-sized gravel (Table IV). Adults exhibited overall selection for all habitat variables tested.

Juveniles exhibited moderate to strong selection (D = +0.34 to +0.96) for depths of 20-30 cm and 50-60 cm, velocities of 20-30 cm/s, over relatively firm substrata (compactions of 4-6 cm) composed of 10-20% fines, 0-10% small-sand, 20-30% coarse-sand, and 60-70% or 80-90% pea-sized gravel (Table IV and Fig. 7). Juveniles did not exhibit overall selection for depth, substratum compaction, and fines composition.

Adults exhibited moderate to strong selection (D = +0.46 to +0.97) for depths of 30-40 and 60-70 cm, velocities of 30-40 cm/s, over looser substrata (compactions of 6-8 cm) composed of 0-10% fines, 20-30% small-sand, 20-30% coarse-sand, and 60 to 70% or 80-90% pea-sized gravel. Adults avoided (D = -0.31 to -1.0) intervals of depth, velocity, substratum compaction, fines, and small-sand selected for by juveniles.

For the three categories of speckled chub abundance in 80 seine-hauls from areas supporting the species, the discriminant function model correctly predicted absence ($\underline{n}$ = 53) 94.3% of the time, rarity ($\underline{n}$ = 22) 27.3% of the time, and commonness ($\underline{n}$ = 5) 100% of the time. Sixteen rare occurrences (1-4 specimens in a seine-haul) were misclassified as absent by the discriminant function model; of these, 11 (68.8%) contained juvenile speckled chub and five (31.3%) contained adults. Seine-hauls with juvenile speckled chub were misclassified more often than those with adults ($\chi^2 = 6.93$; $P < 0.01$).

In areas where speckled chub were absent, absence was correctly predicted for 144 of 160 seine-hauls. The discriminant function model predicted rarity for each of the 16 misclassified seine-hauls. These 16 seine-hauls were made at five of six sites sampled in the South Canadian River and represented 26.7% of the total number of seine-hauls made in that stream. Depth, velocity, compaction, and percent fines in the 16 misclassified seine-hauls from the South Canadian River were within the preferred ranges of juvenile and adult speckled chub, whereas percent small-sand (90-100%) was outside the preferred range of both age classes and no coarse-sand or pea-sized gravel were present. However, a few juveniles were captured in these habitat conditions in the lower Cimarron (5 of 39 seine-hauls; 12.8%) and Salt Fork (1 of 19 seine-hauls; 5.3%) rivers.

Group comparisons (Table IV) indicated seine-hauls from the North and South Canadian rivers (speckled chub effectively extirpated) had significantly lower (ANOVA; $P < 0.001$) percentages of pea-sized gravel and coarse-sand, higher percentages of small-sand and fines, and firmer (lower compaction) substrata than streams supporting speckled chub. The Medicine Lodge River, upper Salt Fork River, and upper-most site on the Cimarron River (M. hyostoma historically absent) were significantly shallower ($P < 0.001$) with more pebble\cobble and coarse-sand and less small-sand than streams supporting the species.

## DISCUSSION

Because speckled chub were not randomly dispersed in the sampling environment (i.e., they exhibited habitat selection) and prior probabilities of group assignment were unidentifiable, ecological importance cannot be assigned to the magnitude of discriminant function coefficients (William, 1983). Nonetheless, general conclusions can still be made from this analysis (Huberty, 1994). For example, the high predictability of the absence of M. hyostoma from individual seine-hauls, based on habitat conditions, indicates the species is a habitat specialist.

My results verify anecdotal comments in the literature regarding habitat correlates of occurrence for speckled chub. A number of authors indicate that speckled chub prefer main channel areas (riffles and runs) of large-rivers with clean sand and gravel substrata and moderate to fast current (Cross, 1967; Pflieger, 1975; Becker, 1983; Boschung et al., 1983; Robison and Buchanan, 1988; Sublette et al., 1990; Page and Burr, 1991). I found that occurrence of adult *M. hyostoma* was associated with presence of clean, pea-sized gravel substrata, which is typically found in runs within the main channel of prairie streams. I also found some evidence for age-class differences, with juveniles most often occupying shallower, slower, water with more fines and less small-sand than areas where adults were captured. Size-specific habitat segregation is common in stream fishes (see Mullen and Burton, 1995; references therein). Avoidance of competition and predation are frequently cited as possible contributing factors in intraspecific habitat segregation (Mullen and Burton, 1995). Fausch (1984) showed that salmonids selected microhabitats that maximize their ability to utilize available prey. Thus, habitat segregation of juvenile and adult *M. hyostoma* may reflect differential distribution of invertebrate food sources (see Cummins and Merritt, 1984); however, this requires further study.

Absence of *M. hyostoma* from areas of previous occurrence in the North and South Canadian rivers was associated with an apparent lack of suitable habitat compared with sites supporting the species in the Cimarron and lower Salt Fork rivers. However, the rarity of historical collection records from the North and South Canadian rivers (Luttrell, 1997) suggests that these streams might have always represented marginal habitat for *M. hyostoma*. Before construction of Eufaula Reservoir, individuals in the study area may have been peripheral components of the population. Long-term persistence of such populations might have been maintained by dispersal from downstream areas, especially after drought periods when reproduction might fail in a species dependent on spring and summer floods. Anthropogenic introduction, possibly as a result of bait transport, may explain the occurrence of a single specimen of *M. hyostoma* in each of two collections from the South Canadian River just upstream of Lake Eufaula in the past five years (J. Pigg, unpubl. data).

Changes in habitat conditions might also help explain the virtual extirpation of the species from the North and South Canadian rivers. Flow regimes in the western streams of the Arkansas River Basin in Oklahoma and Kansas have changed markedly in the past few decades (Cross and Moss, 1987; Wahl and Wahl, 1988; Larson, 1991). Irrigation practices and reservoir construction generally have caused declines in annual flows and in the frequency and magnitude of floods, whereas in some areas, discharge from municipalities has increased the flow.

My analysis also indicated absence of suitable habitat for *M. hyostoma* at sites where it was historically absent, but where *M. tetranema*, another member of the speckled chub complex, once occurred. These sites included the upstream-most sample site in the Cimarron river and all sites in the upper Salt Fork and Medicine Lodge rivers. Lack of suitable habitat may explain the historical absence of _M. hyostoma_ from these areas. Flow records indicate that _M. tetranema_ may have been extirpated from the Cimarron River by drought in 1965-1966 or 1970-1972 and from the upper Salt Fork and Medicine Lodge rivers by drought in 1964 or 1966-1968 (Luttrell, 1997). It is possible that the historical absence of _M. hyostoma_ from these areas was a result of both competition with the more headwater-adapted _M. tetranema_ and habitat characteristics. The importance of habitat characteristics is indicated by the failure of a 1994 attempt to introduce _M. hyostoma_ into the upper Salt Fork and Medicine Lodge rivers, but it is also possible that this failure was a result of poor reproduction during a year when little flooding occurred (Luttrell, 1997).

In conclusion, presence of suitable habitat apparently defines the range of extant _M. hyostoma_ in the Arkansas River Basin. My analysis indicates that absence of the species is associated with an absence of suitable habitat, both in areas of historical extirpation and in areas that once supported the closely related species _M. tetranema_. In the areas of extirpation (North and South Canadian rivers), there is a relative lack of pea-sized gravel substrata associated with occurrence of the species. In areas of historical absence (upper Salt Fork River, Medicine Lodge River, and upper-most Cimarron River site) pea-sized gravel substrata were abundant, but depth and pebble\cobble substrata were outside the range occupied by M. hyostoma elsewhere in the Arkansas River Basin. Sites on the South Canadian River, where M. hyostoma once occurred, now appear unsuitable for the species, although some microhabitats fell within the range of those occupied by juveniles in areas supporting extant populations. The occasional occurrence of a rare specimen of speckled chub in collections from the South Canadian River may result from bait releases. The virtual absence of the species in this region for the past 20 years (Luttrell, 1997) supports my observation that habitat conditions may be inappropriate for the species. Thus, in the absence of further knowledge of habitat availability and suitability, it appears inadvisable to attempt introductions of M. hyostoma into the presently unoccupied areas I examined.

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TABLE IV. Habitat selection by juvenile (*n* = 58) and adult (*n* = 141) *M. hyostoma*. Overall selection shows significance levels (*P*) in tests for non-random distribution on each habitat variable; *ns* = not significant, *P* > 0.05. Electivity shows intervals within habitat variables for which the age-class exhibited moderate to strong selection (see text). D = Electivity.

| | Juveniles | | | Adults | | |
|---|---|---|---|---|---|---|
| | | Electivity | | | Electivity | |
| Variables | Overall selection | Interval | D | Overall selection | Interval | D |
| Depth (cm) | *ns* | 20-30 | 0.42 | <0.01 | 30-40 | 0.71 |
| | | 50-60 | 0.67 | | 60-70 | 0.58 |
| Velocity (cm/s) | <0.01 | 20-30 | 0.73 | <0.001 | 30-40 | 0.89 |
| Compaction (cm) | *ns* | 4-6 | 0.61 | <0.01 | 6-8 | 0.74 |
| Fines (%) | *ns* | 10-20 | 0.34 | <0.01 | 0-10 | 0.58 |
| Small-sand (%) | <0.001 | 0-10 | 0.74 | <0.001 | 20-30 | 0.97 |
| | | 10-20 | 0.47 | | | |
| Coarse-sand (%) | <0.01 | 20-30 | 0.96 | <0.001 | 20-30 | 0.97 |
| Pea-sized gravel (%) | <0.001 | 60-70 | 0.76 | <0.001 | 60-70 | 0.97 |
| | | 80-90 | 0.88 | | 80-90 | 0.46 |

TABLE V. Back-transformed means and standard deviations of habitat variables from ANOVA in seine-hauls from areas where *M. hyostoma* was present, historically absent, and extirpated (see text for explanation of groups). Means with the same superscript were not significantly different (Tukey's HSD, " = 0.01) between groups. *n* = number of seine-hauls. *ns* = not significant (ANOVA; *P* > 0.01).

| | Present *n* = 80 | | Absent *n* = 70 | | Extirpated *n* = 90 | | | |
|---|---|---|---|---|---|---|---|---|
| Variables | $\bar{x}$ | *SD* | $\bar{x}$ | *SD* | $\bar{x}$ | *SD* | F | *P* |
| Depth (cm) | 35.08[a] | 19.84 | 16.34 | 9.77 | 28.91[a] | 15.66 | 45.23 | < 0.001 |
| Velocity (cm/s) | 17.50 | 13.05 | 17.42 | 7.65 | 15.09 | 12.17 | 3.11 | *ns* |
| Compaction (cm) | 3.95[b] | 2.42 | 3.36[b] | 0.63 | 2.82 | 0.92 | 9.16 | < 0.001 |
| Fines (%) | 8.44[c] | 11.49 | 4.79[c] | 7.14 | 17.78 | 10.33 | 36.88 | < 0.001 |
| Small-sand (%) | 43.44 | 31.81 | 29.40 | 15.71 | 73.50 | 18.65 | 63.94 | < 0.001 |
| Coarse-sand (%) | 24.50 | 23.78 | 40.67 | 18.80 | 6.50 | 12.77 | 61.56 | < 0.001 |
| Pea-sized gravel(%) | 20.75[d] | 24.55 | 20.86[d] | 15.70 | 1.56 | 4.22 | 35.07 | < 0.001 |
| Pebble\Cobble (%) | 1.25[e] | 3.33 | 4.29 | 7.34 | 0.67[e] | 3.28 | 12.13 | < 0.001 |
| Boulder (%) | 0.50 | 4.47 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | *ns* |
| Bedrock (%) | 1.13 | 7.46 | 0.00 | 0.00 | 0.00 | 0.00 | 1.79 | *ns* |

Fig. 6. Locations of 24 sites in the Arkansas River Basin where collections were made in 1994 and 1995. Specific locality information appears in Appendix C. Black circles = sites where *M. hyostoma* was captured; open circles = sites where *M. hyostoma* was absent; A = Lake Eufaula; B = Great Salt Plains Reservoir; C = Deep Fork River. Inset shows approximate geographical location of the study area.

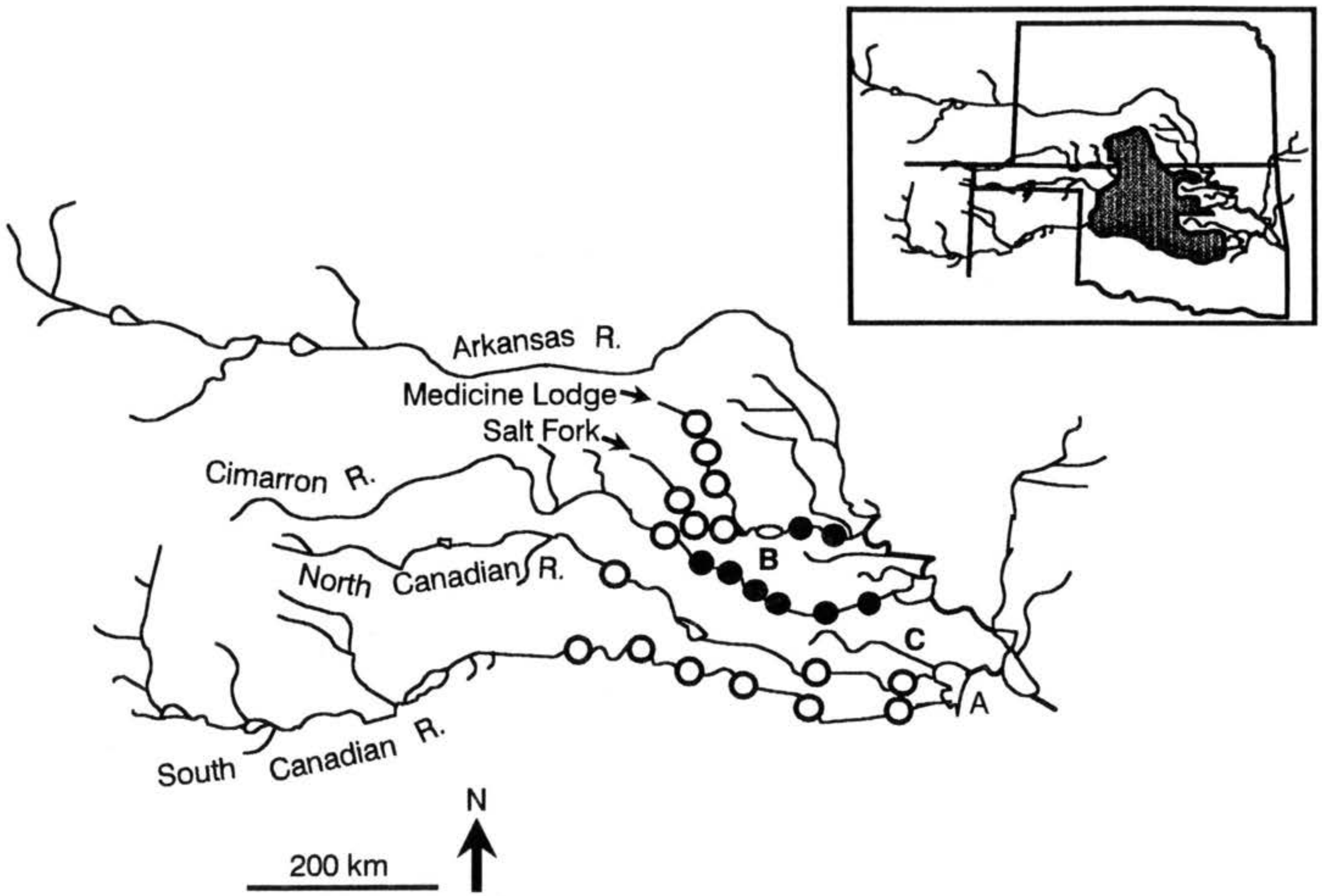
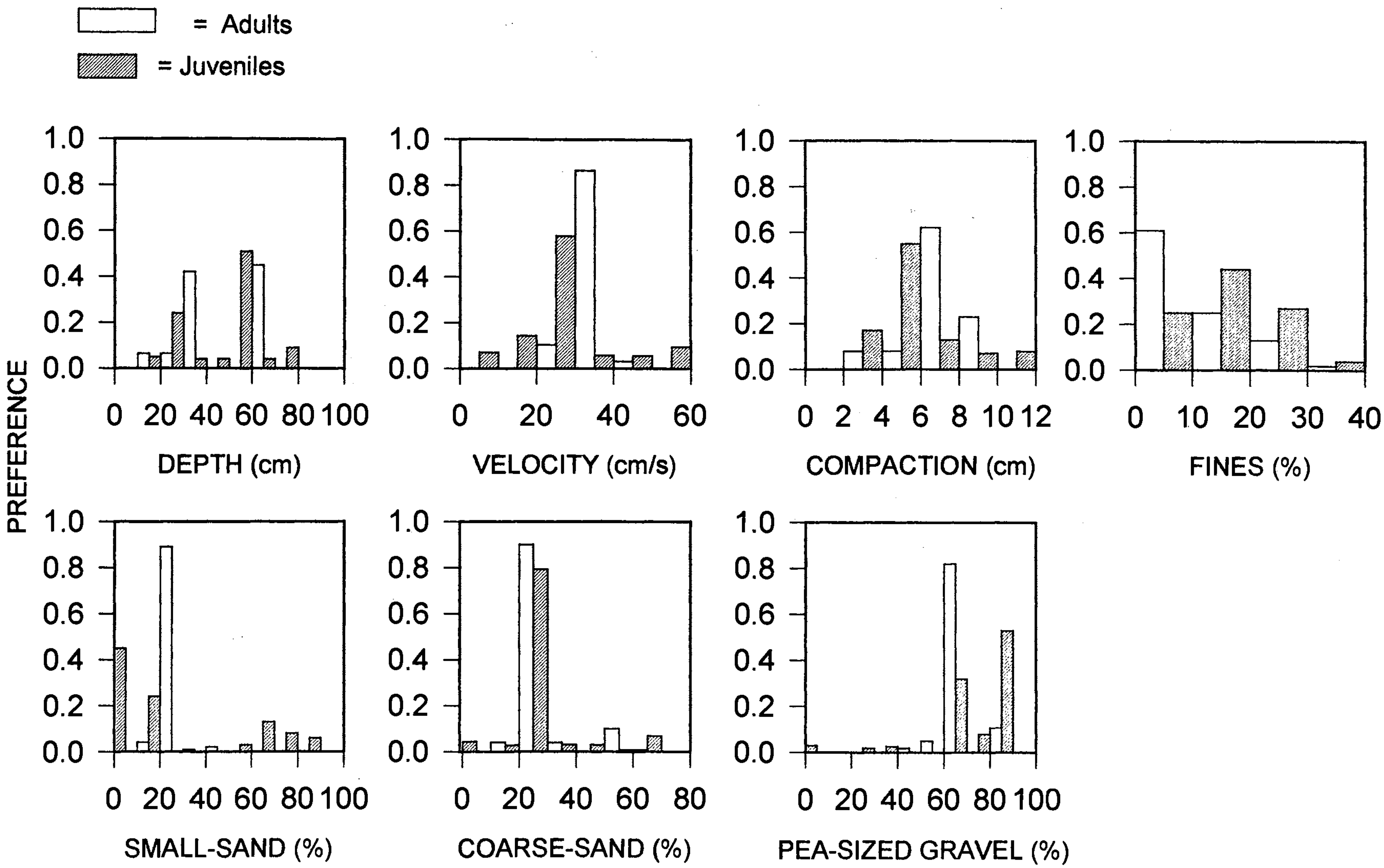

Arkansas R.
Medicine Lodge
Salt Fork
Cimarron R.
North Canadian R.
South Canadian R.
B
C
A
N
200 km

Fig. 7. Habitat preferences (normalized ratio) of adult (*n* = 141) and juvenile (*n* = 58) *M. hyostoma*.


= Adults
= Juveniles
PREFERENCE
DEPTH (cm)
VELOCITY (cm/s)
COMPACTION (cm)
FINES (%)
SMALL-SAND (%)
COARSE-SAND (%)
PEA-SIZED GRAVEL (%)

CHAPTER III

# RE-ESTABLISHMENT OF A MEMBER OF THE SPECKLED CHUB COMPLEX (CYPRINIDAE: *MACRHYBOPSIS HYOSTOMA*) IN THE CIMARRON RIVER OF OKLAHOMA

## INTRODUCTION

This paper documents the re-establishment of a population of *Macrhybopsis hyostoma*, a cyprinid fish of the speckled chub complex, approximately 20 years after its apparent extirpation from the Cimarron River in north-central Oklahoma. The Cimarron River is a large western tributary of the Arkansas River in Oklahoma and Kansas. To my knowledge there are no other documented instances where, with apparently little or no human intervention, a native fish population has been restored to a large-river environment.

A morphological study of the speckled chub complex (cf. *Macrhybopsis aestivalis*) demonstrates that *M. hyostoma* occupies several of the larger rivers in the Mississippi River Basin (D. Eisenhour, pers. comm.). In the Arkansas River drainage of Oklahoma, the historic range of *M. hyostoma* includes the Arkansas River mainstem and downstream reaches of its western tributaries. Until the re-establishment reported here for the Cimarron River, *M. hyostoma* was considered extirpated from all except one of four major western tributaries of the Arkansas River in Oklahoma (Luttrell, 1997).

The study by D. Eisenhour (pers. comm.) demonstrates that the Cimarron River population of *M. hyostoma* once occurred sympatrically with *M. tetranema*, another member of the speckled chub complex. In this paper, I document extirpation of Cimarron River populations of both species between 1965 and 1976. I then document re-establishment of *M. hyostoma* in the river, possibly as a result of dispersal from the Arkansas River via Keystone Reservoir, a large impoundment covering the historic confluence of the Cimarron and Arkansas rivers.

## MATERIALS and METHODS

The historical distributions of *M. tetranema* and *M. hyostoma* in the Cimarron River drainage (Fig. 8) were delimited by examination of museum specimens by D. Eisenhour (pers. comm.) and/or by myself. The temporal pattern of occurrence of speckled chub and the number of collections at sites in the Cimarron River were evaluated from museum records (Appendix A), published literature (Hubbs and Ortenburger, 1929; Moore and Mizelle, 1939; Cross, 1950;

Harrel, 1966; Wade and Craven, 1966; Marshall, 1978; Felley and Cothran, 1981; Wallace, 1980; Pigg, 1988; Larson, 1991), and unpublished field-notes (G. A. Moore, F. B. Cross, J. Pigg, R. D. Larson) on file in the Oklahoma State University Vertebrate Collections.

As a part of a broader survey of the status of speckled chub in the Arkansas River Basin (Luttrell, 1997), I used nylon-seines (3.6- or 7.6-m long, 1.8-m deep, with 3.2-mm mesh) to collect the species from the Cimarron River drainage. From 1992 to 1995, I made 39 collecting visits to 18 sites on the Cimarron River mainstem and 61 visits to 26 sites on tributaries (Appendix B).

Daily streamflow data from a site near Perkins, Payne Co., OK (U.S. Geological Survey: station number 07161000) were reviewed to assess flow conditions associated with extirpation of *M. tetranema* and *M. hyostoma* from the drainage. Maximum mean daily flows for each month of the May-to-August spawning season were examined for a period when speckled chub were known to be present (1940-1962) and compared with similar data for a period of years (1963-1976) when the two species apparently were extirpated.

# RESULTS

## Disappearance of speckled chub from the Cimarron River

The historical distributions of *M. tetranema* and *M. hyostoma* in the Cimarron River drainage (Oklahoma and Kansas) are illustrated in Figure 8. The temporal and spatial occurrence of the two species in collections from the Cimarron River mainstem in Oklahoma is shown in Figure 9. Historically, *M. tetranema* was more wide-spread and abundant than *M. hyostoma*. Between 1928 and 1965, 455 specimens of *M. tetranema* were taken in 23 collections of the species from the Cimarron River mainstem and 184 specimens were taken in 10 collections of the species from tributaries of the river (Appendix A). During the same period, there were only three collections of *M. hyostoma* from the drainage, all of which were from the mainstem; these collections were made in 1935 (8 specimens), 1960 (10 specimens), and 1965 (1 specimen).

Until 1992, the last record of speckled chub from the Cimarron River drainage was a collection (OKMNH 33985) of five *M. tetranema* and one *M. hyostoma* from the Cimarron River N of Guthrie, Logan Co., Oklahoma. Pigg (1988) reported collecting five specimens of speckled chub from the Cimarron River near Perkins, Payne Co., Oklahoma, in 1984. However, these specimens were identified as *Hybognathus* placitus in his personal field-notes but tabulated as Hybopsis (= Macrhybopsis) aestivalis in records compiled for his agency (Oklahoma Dept. of Environmental Quality). Copies of both records were deposited in the Oklahoma State University Collection of Vertebrates. These observations, together with the otherwise long period during which speckled chub were absent from the drainage, suggest the 1984 record was a data-entry error.

Between 1976 and 1992, more than 400 collections were made in the Cimarron River drainage, and none contained either species of speckled chub (Marshall, 1978; Felley and Cothran, 1981; Pigg, 1988; Pigg, unpubl. field notes; Larson, 1991; Luttrell, 1997). Between 1976 and 1991, 287 of these collections were from the Cimarron River mainstem within the historical range of speckled chub in Oklahoma.

Detection of species absence with confidence is problematic. Following Reed (1996), the number of site visits ($\underline{N}$) needed to conclude with a desired confidence level ($\alpha$) that a species is absent from an area is given by the equation $\underline{N} = [\ln(\alpha \text{ level})] \bullet [\ln(1 - \underline{P})]^{-1}$, where $\underline{P}$ is estimated detectability per site visit. With 287 visits to Cimarron River mainstem sites, and assuming speckled chub were extremely rare (i.e., $\underline{P} = 0.05$; five of 100 site-visits would produce one or the other species), the probability they were present but not detected in these visits is about

$4.0 \times 10^{-7}$.

Reappearance of speckled chub in the Cimarron River

The first post-1965 collections of speckled chub (*M. hyostoma*) from the Cimarron River Basin were made by R. P. Lemmons (pers. comm.) in September 1992 from two sites on the lower Cimarron River in Oklahoma (Fig. 9). These included three specimens from near Oilton, Creek Co. (OKMNH 51563) and one specimen from near Cushing, Payne Co (OKMNH 51562). These two sites were sampled in 1979 (Felley and Cothran, 1981) and again in 1989 (Larson, 1991) and produced no speckled chub. In 1992, speckled chub were absent in 32 samples from 11 mainstem sites (Fig. 9) upstream of the two sites where Lemmons collected the species (Pigg, unpubl. data; Lemmons et al., in litt; Luttrell, 1997).

In 1993, I sampled the Cimarron River at 12 mainstem sites from Oilton upstream about 264 stream-km to Cleo Springs (Major Co., Oklahoma). I found *M. hyostoma* at all 10 sites sampled between Oilton and Dover (Kingfisher Co.), but failed to find it at two sites farther upstream, one about 29 km upstream of Dover, near Okeene, Kingfisher Co., and another about 44 km upstream of Okeene, near Cleo Springs, Major Co. Pigg (unpubl. data) collected a single specimen of *M. hyostoma* at each of these last two sites in 1994. In 1995 I collected 35 specimens at the Okeene site and 95 at the Cleo Springs site (Fig. 9). Also in 1995, I attempted unsuccessfully to collect the species about 53 km upstream of Cleo Springs, near Waynoka, Woods Co., Oklahoma.

In the summers of 1993, 1994, and 1995 I collected 343 *M. hyostoma* from the Cimarron River mainstem (Fig. 9). In 1993, 92 specimens [SL = 12 to 35, $\bar{x}$ = 19.9-mm, *SD* = 6.1], all less than one year-old, were taken at 10 sites between 24 June and 17 August. In 1994, 44 specimens [SL = 10 to 50, $\bar{x}$ = 33.5-mm, *SD* = 13.4], 30 (68%) of which were more than one year-old, were taken at four sites between 23 June and 4 August. In 1995, 128 specimens [SL = 26 to 55, $\bar{x}$ = 42.2-mm, *SD* = 6.71], 111 (87%) of which were more than one year-old, were collected from three sites between 14 July and 14 August. An additional 79 specimens were taken from three sites (1995-1996) and frozen for genetic analysis (no measurements were made). No specimens of *M. tetranema* were encountered anywhere in the drainage. Statistical analysis of size distributions were not attempted because streamflow conditions precluded systematic temporal sampling of several stream sites.

Mean daily discharge records for the Cimarron River near Perkins show two periods of consecutive years (1965-1966 and 1970-1972) when May-to-August streamflows were consistently low (<5,600 CFS) relative to other years within the period (1965-1976) when speckled chub apparently disappeared from the stream (Fig. 10). This pattern of consistently low-flows through consecutive spawning-seasons was not seen elsewhere in the period of record (1940-1990). Prior to closure of Keystone Dam in 1964, flows $< 5,600$ CFS occurred in the breeding seasons of 1953, 1956, and 1959. Longevity of individuals in the speckled chub complex is probably less than two years (Starrett, 1951), and reproduction apparently depends on flood events (Bottrell et al., 1964). Thus, consecutive years with minimal flooding could lead to extirpation of the species.

## DISCUSSION

There are at least three possible explanations for the re-appearance of *M. hyostoma* in collections from the Cimarron River. First, a population may have persisted without detection from the early 1970s to 1992. This seems unlikely, however, because of the numerous collections from the Cimarron River in this time interval. Further, the temporal pattern of collections suggests re-establishment of a new population (Fig. 9). After more than two decades of going undetected, the species was collected in 1992 from two downstream sites and remained undetected in upstream areas. In the following year, the species was found throughout approximately 191 stream-kilometers representing the approximate limits of its historic range in the Cimarron

River. The size-distribution of individuals further indicates progressive re-establishment of a population. In 1993, all samples contained small, young-of-year individuals, whereas 1994 and 1995 samples contained adults.

Accidental introduction, possibly as a result of bait transport, may explain re-appearance of M. hyostoma in the Cimarron River. The potential for this is indicated by the apparently accidental introduction of Red River shiner, Notropis bairdi, into the Cimarron River between 1964 and 1972 (F. B. Cross, pers. comm.). This species, formerly endemic to the Red River, was wide-spread and firmly established in the Cimarron River by 1979 (Felley and Cothran, 1981). The temporal change in the distribution of speckled chub in the Cimarron River indicates that, if reappearance of the species was a result of human transport, the introduction occurred in a downstream area, in or near Keystone Reservoir.

An alternative explanation is that the downstream-to-upstream spread of the species in the Cimarron River resulted from a natural founding population derived from the Arkansas River, possibly by way of Keystone Reservoir. Speckled chub seem adapted to riverine, flowing water habitats and, except on rare occasions (Echelle et al., 1971), they are not found in reservoirs. Re-establishment of the Cimarron River population after 20 years may have resulted from chance dispersal from a sparse, perhaps transitory, reservoir population.

Aspects of speckled chub life history suggest that, in the past, re-invasions into areas of extirpation would have occurred rather rapidly. A study of speckled chub in the Cimarron River (either M. tetranema or M. hyostoma, or both) indicates that spawning occurs during flood events and that the semi-buoyant eggs develop as they drift downstream (Bottrell et al., 1964). Thus, to some extent, maintenance of upstream populations would have been dependent on upstream migration. Correspondingly, in May 1994 I encountered unusually dense aggregations (100 to 200 individuals per haul of a 7.6-m seine) of ripe male and female M. hyostoma in the Kaw Reservoir spillway (Arkansas River, Osage/Kay Co., Oklahoma). These aggregations were concentrated immediately downstream of the spillway, despite the presence of seemingly suitable habitat a few hundred meters downstream where I was unable to collect the species. This suggests Kaw Dam was blocking upstream dispersal of adults.

Macrhybopsis hyostoma persisted in the Arkansas River, both upstream and downstream of Keystone Reservoir, throughout the 20-year absence of the species from the Cimarron River (Luttrell, 1997). It seems likely that, without the barrier presented by Keystone Reservoir, extirpation of the Cimarron River population might have gone unnoticed because of rapid re-invasion and subsequent reproduction by individuals from the Arkansas River. The rapid expansion of *M. hyostoma* in the Cimarron River between 1992 and 1993 attests to the high reproductive potential (Starrett, 1951; Becker, 1983) of the species.

*Macrhybopsis hyostoma* now occupies all of its former range in the Cimarron River. Thus, its extirpation in the late 1960s or early 1970s apparently was not a result of altered habitat conditions. Consecutive years with consistently low-flow during the spawning season (e.g., 1965-1966 or 1970-1972), may explain the disappearance of both *M. hyostoma* and *M. tetranema* from the Cimarron River. Only *M. hyostoma* could have re-invaded from downstream because, historically, *M. tetranema* has been essentially absent from the Arkansas River mainstem in Oklahoma (D. Eisenhour, pers. comm.; Luttrell, 1997) -- a single specimen of *M. tetranema* was taken from the Arkansas River near Keystone, Pawnee Co. in 1960 (OKMNH 39032).

Re-establishment of *M. hyostoma* in the Cimarron River demonstrates the potential for successful reintroductions into other areas where speckled chub have been extirpated. However, attempts at reintroduction are futile if the causes of extirpation still remain. My analysis of habitat suitability for *M. hyostoma* in two areas of former occurrence, the North and South Canadian rivers in Oklahoma (Luttrell, 1997), indicates that these rivers may not be suitable for reintroductions. Historically, speckled chub collections from these streams were rare, suggesting that habitat conditions have always been marginal for the species. Persistence of *M. hyostoma* in these streams may have depended on dispersal from downstream areas with more optimal habitat (Luttrell, 1997). The species still occurs in the Canadian River downstream of Eufaula Reservoir and it recently reappeared (two specimens since 1992) in the South Canadian River (J. Pigg, unpubl. data) upstream of the reservoir. Whether these collections represent an extant population or recent anthropogenic introductions (e.g., bait transport) is unclear; however, the latter is suggested by absence of the species in collections from this area between 1965 and 1992, a paucity of its preferred pea-gravel substrata, and an apparent failure of the species to increase in abundance between 1992 and 1995.

When absence of a species in part of its historic range is a result of man-made barriers to dispersal, management agencies should consider implementing reintroduction programs before changes in community structure occur that preclude successful re-establishment of the species. For example, reintroduction of Arkansas River shiner (*N. girardi*) in the Cimarron River may now be precluded by presence of a dense population of Red River shiner (Notropis bairdi), a morphologically similar, introduced species.

Disturbance of metapopulation dynamics by reservoir construction may be a major contributing factor in the decline of several midwestern stream-fishes. A number of prairie-species (e.g., Arkansas River shiner, plains minnow, speckled chubs) are dependent on flooding for successful reproduction (Moore, 1944; Starrett, 1951; Bottrell et al., 1964; Cross, 1967; Bestgen et al., 1989; Taylor and Miller, 1990). These species seldom live more than two years. Thus, two or three successive years with minimal flooding during spring and summer months would likely result in poor reproduction and heightened chances of extirpation. In the past, areas of extirpation would have been recolonized by dispersal from other parts of geographically extensive metapopulations. Now, however, reservoirs and their dams impede recolonization in much of the Arkansas River Basin. This apparently explains the 20-year absence of M. hyostoma from the Cimarron River (this study) and virtual absence of the species from the North Canadian, South Canadian, and Deep Fork rivers upstream of Lake Eufaula (Luttrell, 1997). Extirpation by drought and the presence of a reservoir downstream apparently explains the absence of several prairie-stream fishes in areas of historical occurrence. These include speckled chub (cf. M. aestivalis) in a portion of the Red River System in southwestern Oklahoma (Winston et al., 1991), *M. tetranema* throughout much of its former range in the Arkansas River System (Luttrell, 1997), and perhaps *N. girardi* over portions of its native range (Larson, 1991).

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Fig. 8. Historical distribution of speckled chub (1928-1965) in the Cimarron River drainage (Luttrell, 1997). Shaded circles = records of *M. tetranema*; squares = co-occurrence of *M. hyostoma* and *M. tetranema*. Inset shows the study area in Oklahoma and Kansas.

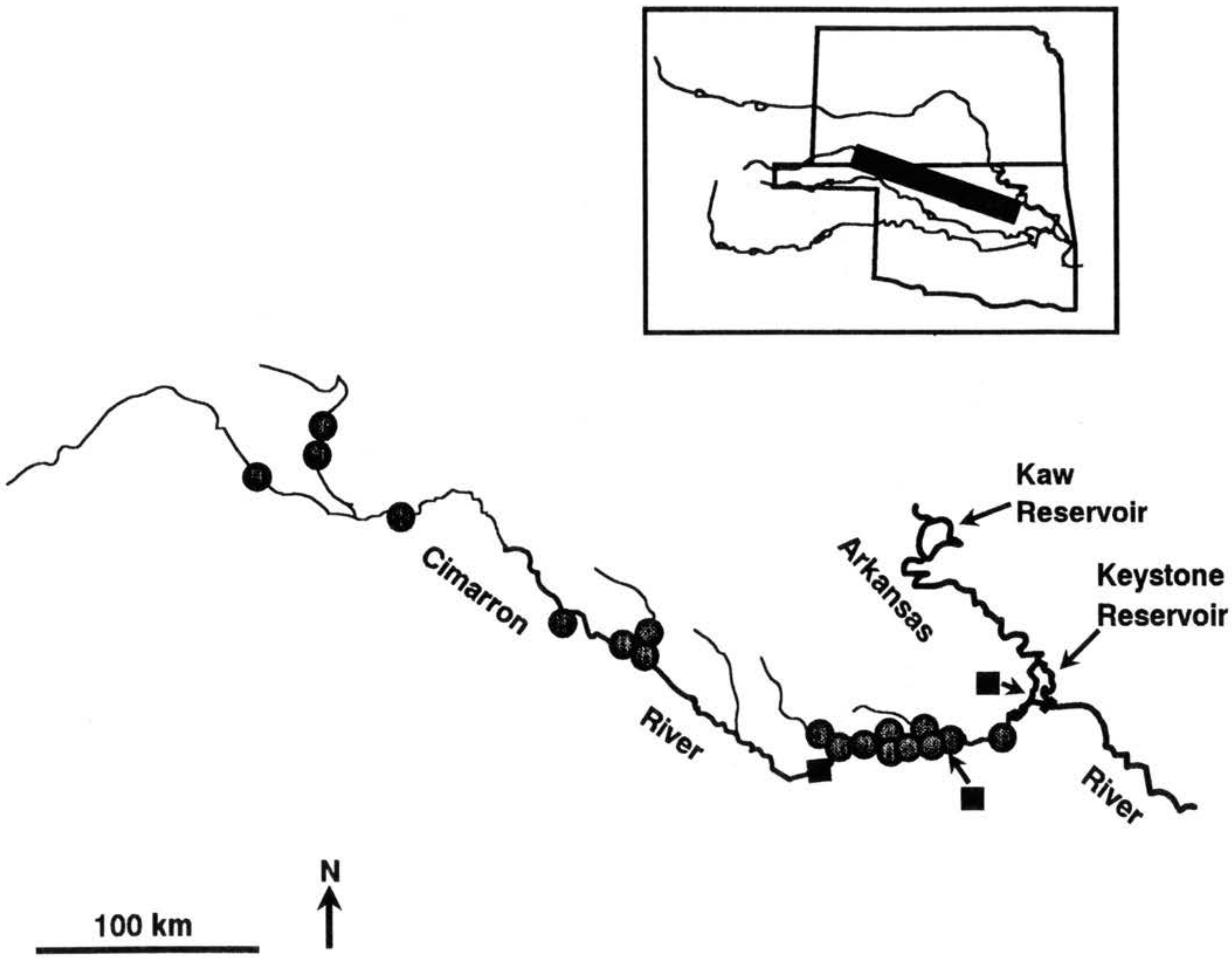
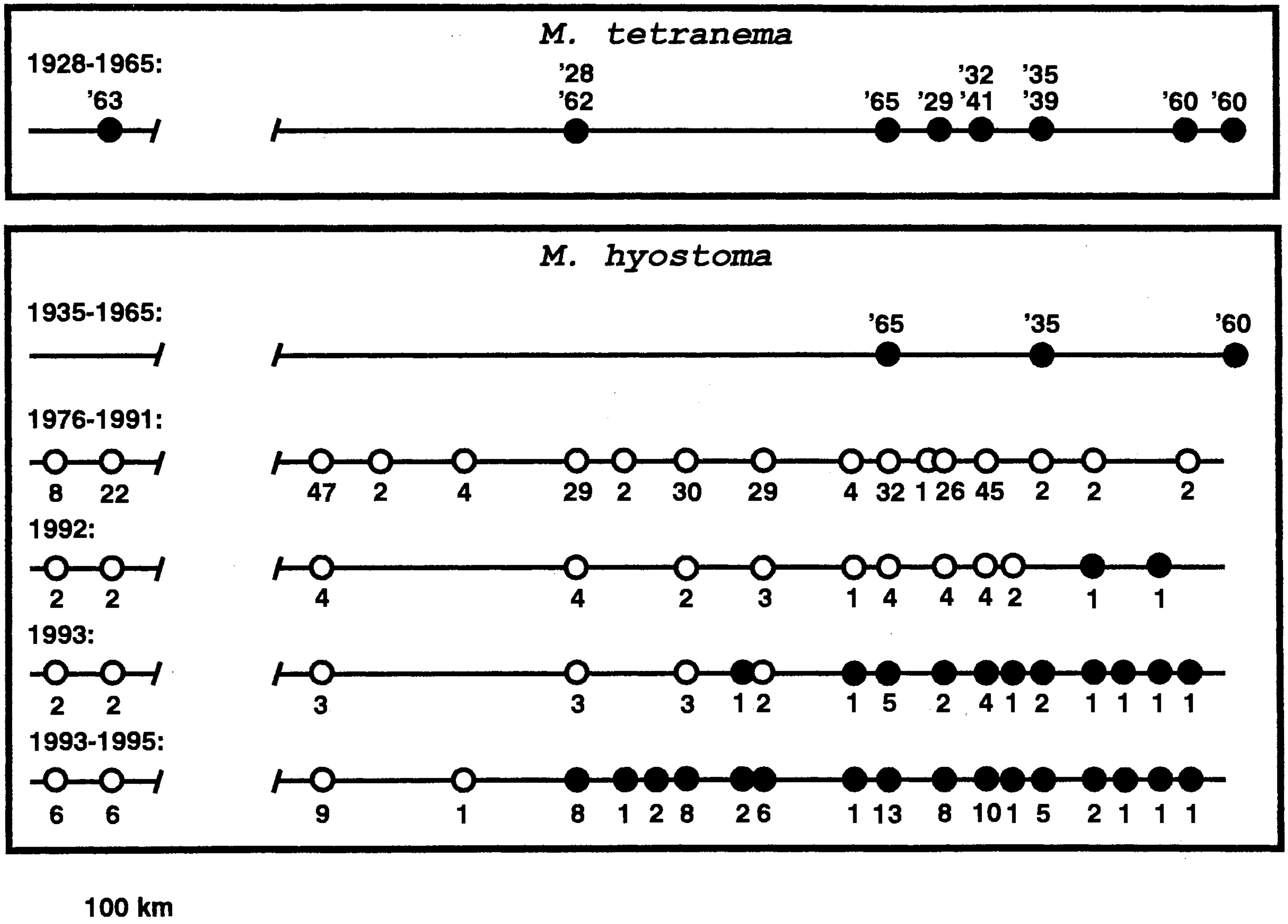
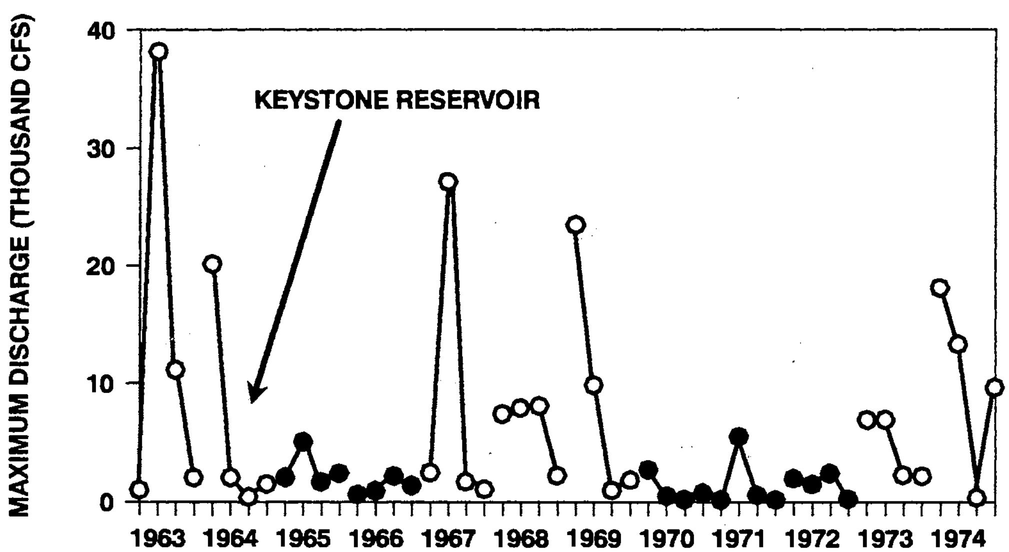

Kaw
Reservoir
Keystone
Reservoir
Cimarron
River
Arkansas
River
100 km
N

Fig. 9. Summary of changes in the distribution of _M. hyostoma_ and _M. tetranema_ in the Cimarron River. Shown are Oklahoma segments of the Cimarron River mainstem from north-central Beaver County through northwest Harper County (shorter line segments on the left) and from northeast Harper County downstream to confluence with the Arkansas River (line segments on the right). Data are from museum records (Appendix A) and collections reported by Marshall (1978), Felley and Cothran (1981), Pigg (1988, and unpubl. data), Larson (1991), Lemmons et al. (in litt.), and Luttrell (1997). Open circles = collections not containing speckled chub; black circles = collections containing speckled chub. Numbers below each line indicate number of collections at that site, numbers above the line indicate year of collection.



M. tetranema
1928-1965:
'63
'28
'62
'65
'29
'32
'41
'35
'39
'60
'60
M. hyostoma
1935-1965:
'65
'35
'60
1976-1991:
8 22
47 2 4 29 2 30 29 4 32 1 26 45 2 2 2
1992:
2 2
4 4 2 3 1 4 4 4 2 1 1
1993:
2 2
3 3 3 1 2 1 5 2 4 1 2 1 1 1 1
1993-1995:
6 6
9 1 8 1 2 8 2 6 1 13 8 10 1 5 2 1 1 1
100 km

Fig. 10. Maximum daily stream flow for the Cimarron River at Perkins. Plotted data are maximum daily flows for May-August of 1963-1974. The last pre-1992 collection of speckled chub from the river was made in 1965, the year following closure of Keystone Dam. Closed circles = years when May-August flows never exceeded 5,600 CFS.


MAXIMUM DISCHARGE (THOUSAND CFS)
KEYSTONE RESERVOIR
40
30
20
10
0
1963 1964 1965 1966 1967 1968 1969 1970 1971 1972 1973 1974

# CHAPTER IV

## AN ATTEMPTED INTRODUCTION OF A MEMBER OF THE SPECKLED CHUB COMPLEX (CYPRINIDAE: cf. MACRHYBOPSIS AESTIVALIS) INTO AREAS OF PAST OCCURRENCE

### INTRODUCTION

Transplantation of species to previously occupied sites within their native range (reintroduction) is popular with conservation biologists (Booth, 1988; Brown, 1988; Conway, 1988; Griffith et al., 1989; Wikramanayake, 1990; Hendrickson and Brooks, 1991) and is recommended in most recovery plans for endangered fishes (Williams et al., 1988). Reintroductions have been particularly common in the southwestern United States (Hendrickson and Brooks, 1991). Williams et al. (1988) and Hendrickson and Brooks (1991) emphasized the need for documentation and publication of reintroduction attempts to aid future researchers. In this paper, I report an attempt to reintroduce speckled chub (Cyprinidae: cf. *Macrhybopsis aestivalis*) to the Salt Fork of the Arkansas (= Salt Fork) and Medicine Lodge rivers of Oklahoma and Kansas. I examine habitat and streamflow conditions and discuss additional factors that may have contributed to the failure of this effort.

Members of the speckled chub complex are small cyprinids ($\leq$ 76 mm SL) that live about 1.5 years (Becker, 1983; Starrett, 1951). They apparently spawn during spring and summer spates, and the eggs drift downstream suspended in current until they hatch in 24 to 28 hours (Bottrell et al., 1964). Larvae drift downstream as they develop and later life-stages apparently disperse upstream.

The last known collection of speckled chub in the Salt Fork River drainage upstream of Great Salt Plains Reservoir was made in 1964, over two decades after completion of Salt Plains Dam in 1941 (Luttrell, 1997). Extirpation of the species appears associated with unusually low flows during the May-August spawning periods in 1964, and 1966-1968 (Luttrell, 1997). The presence of Salt Plains Dam would have prevented recolonization from downstream. Similar circumstances explain the disappearance of speckled chub from the upper North Fork of the Red River in southern Oklahoma (Winston et al., 1991).

In 1994, I attempted to reintroduce speckled chub into the Medicine Lodge and Salt Fork rivers upstream of Great Salt Plains Reservoir. Qualitative observations indicated that habitat conditions in these streams were adequate, and I assumed that the high reproductive potential of speckled chub (Starrett, 1951; Becker, 1983) would allow rapid establishment of a population.

In an ongoing study of speckled chub systematics, and subsequent to my attempted reintroduction, D. Eisenhour (pers. comm.) concluded that several nominal subspecies of *M. aestivalis* should be elevated to species status. His work indicates that two species of speckled chub formerly occurred in the Salt Fork River drainage; *M. tetranema* in the Medicine Lodge and Salt Fork rivers upstream of Great Salt Plains Reservoir and *M. hyostoma* in the Salt Fork River downstream of the reservoir. The two species co-occurred only immediately downstream of the reservoir (Fig. 11). Thus, without knowing of Eisenhour's work, my efforts to reintroduce speckled chub into stream reaches upstream of Great Salt Plains Reservoir resulted in the release of *M. hyostoma* in an area previously occupied only by *M. tetranema*.

## MATERIALS and METHODS

In March of 1994, I explored the Salt Fork and Medicine Lodge rivers upstream of Great Salt Plains Reservoir to locate suitable habitat for speckled chub. I chose two sites (Fig. 12), one on the Salt Fork River near Alva, Woods Co., Oklahoma (T27N R13W, R14W S13, S18) and a second on the Medicine Lodge River near Lake City, Barber Co., Kansas (T31S R14W S14). These sites were chosen based on former occurrence of speckled chub, presence of pea-sized gravel substrata required by members of the complex (Luttrell, 1997), and stream accessibility by automobile.

During May 1994, four collections of speckled chub (now known to have been *M. hyostoma*) were made from an unusually dense aggregation immediately downstream of the Kaw Reservoir spillway on the Arkansas River, Kay\Osage Co., Oklahoma (Fig. 12). Following capture with seines, individuals were counted, placed in an aerated 94.6-liter insulated tank, transported to one or the other of the release sites, thermally acclimated to within 2°C of the receiving water temperature by addition of stream water to the hauling-tank, and released. All fish rapidly swam away following release. All releases occurred within four to six hours of initial capture. Thermal acclimation periods ranged from one-half to two hours with temperature changes $\leq$ 3°C per hour.

About 1340 specimens of *M. hyostoma* were released at the Lake City site on the Medicine Lodge River, 600 on 17 May and 740 on 18 May 1994. The Alva site on the Salt Fork River received about 591 specimens, 400 on 19 May and 191 on 25 May 1994. A sample (OSUS 26784; *n* = 143) from the capture site on 26 May ranged from 37 to 67 mm in SL ($\bar{x}$ = 48 mm, *SD* = 3.87) and contained 65 males and 78 females. The fish released at the reintroduction sites were adults or sub-adults that should have spawned in 1994 (Starrett, 1951), and releases were made in mid-May near the start of a May-August breeding season (Cross, 1967). Many of the released females were visibly gravid, and released eggs with slight pressure to their distended abdomens. Introduction efforts were limited to May 1994 to prevent depletion of speckled chub at the capture site. I was unsuccessful in efforts to collect sufficient numbers of the species, for subsequent introduction attempts, elsewhere in the drainage.

## Habitat Measurements

In July and August 1994, I made habitat measurements and attempted to collect speckled chub at the two release sites and, for comparative purposes, at two sites on the lower Salt Fork River (downstream of Great Salt Plains Reservoir) where the speckled chub had not been extirpated. Habitat measurements and attempts to collect the species were made at four additional sites, two on each stream, upstream of Great Salt Plains Reservoir in August 1995 (Fig. 12).

Sampling consisted of 10 downstream seine-hauls (1.8-m by 7.6-m seine with 3.2-mm mesh) covering 1,000 to 1,520 $m^2$ in, or adjacent to, the main channel within a 1.5- to 2.0-km stream reach. Main channel habitats were distinguished as the cross-sectional stream portion with the highest evident surface velocity; in prairie streams these areas usually have the deepest waters and coarsest substrata (pers. observ.). For each seine-haul, area ($m^2$) seined was measured, and depth (cm), velocity (cm/s), substratum compaction (cm), and percent composition of seven substratum particle sizes were recorded at five or six points within the area seined. Measurements were made at five points (four corners and center) when seine-haul area was < 150 $m^2$ and six points (four corners and two near center) when the area was > 150 $m^2$.

A metered wading-rod (3-cm diameter) was used to measure depth and substratum compaction. The rod was field-calibrated with a Pygmy-Gurley current meter to approximate current velocity at 0.60 depth from the surface. Difference in water height (cm) on the upstream and downstream sides of the rod was converted to velocity in cm/s using the following regression equation ($\underline{n} = 60$, $\underline{r}^2 = 0.59$, $\underline{P} < 0.01$, Standard Error of Estimate = 0.085): Velocity in cm/s = 0.138386 + 0.068903 • difference in water height. Substratum compaction was recorded as the distance the rod penetrated the substratum when a 10-kg force was applied.

Substrata were assessed by scooping into the stream bottom with a wide-mouthed 470-ml jar until it was full, then covering the jar and raising it to the surface and pouring out the contents. Percent abundance of fines (<1 mm), small-sand (1-2 mm), coarse-sand (2-5 mm), and pea-sized gravel (5-9 mm) were then visually estimated (Luttrell, 1997). Abundance of pebble\cobble (9-250 mm), boulder ($\geq$ 250 mm), and bedrock were estimated from six hand-grab samples made within a 0.75-$m^2$ area centered around the rod at each sample point measurement; i.e., 30 or 36 grab samples per seine-haul. For analytical purposes, each seine-haul was characterized by the mean for each habitat variable.

In addition to collection efforts associated with habitat measurements (six collections at six sites), I made 19 presence-absence collections at 17 sites, 10 in the upper Salt Fork River and seven in the Medicine Lodge River, to document presence-absence of speckled chub (Fig. 12). At each site, six to eight 20- to 30-m seine-hauls (1.8-m by 7.6-m seine with 3.2 mm mesh) were made in the downstream direction, in, or adjacent to, the main channel.

Data Analyses

Arcsin (for percentages) and natural log (all other data) transformations improved normality and homoscedasticity of habitat data. To compare habitat differences among streams I used analysis-of-variance (ANOVA; $\alpha = 0.01$) with hierarchically nested effects (i.e., seine-haul within site within stream) to account for within-stream variation in testing among-stream differences (Steel and Torrie, 1980). Multiple comparison of stream means were performed using Tukey's HSD ($\alpha = 0.01$). The objectives of this analysis were to determine if habitat conditions in the Medicine Lodge and upper Salt Fork rivers differed from those in the lower Salt Fork and Cimarron rivers where speckled chub still occur. Cimarron River habitat data (Luttrell, 1997) were obtained as described for the study area.

Detection of species absence with confidence is often problematic. I used Reed's (1996) equation, $\underline{N} = [\ln(\alpha\ \text{level})] \cdot [\ln(1 - \underline{P})]^{-1}$, to determine number of site visits ($\underline{N}$) needed to conclude with 95% confidence ($\alpha = 0.05$) that speckled chub were absent upstream of Great Salt Plains Reservoir. I considered the entire study area one site, and each visit to the area was treated as a site-visit. I assumed that the species was sufficiently rare that species detectability ($\underline{P}$) was 0.15; i.e., the species would be collected in 15 out of 100 visits to the study area.

United States Geological Survey daily streamflow data from two stations, one on the Medicine Lodge River and one on the upper Salt Fork River, were analyzed. Flow data from a site on the Medicine Lodge River near Kiowa, Kansas (station number 07149000) and a site on the upper Salt Fork

River near Alva, Oklahoma (station number 0714800) were used to evaluate flow conditions surrounding the 1994 reintroduction of speckled chub (Fig. 13).

## RESULTS

Sampling efforts at the release sites in August 1994, June 1995, January 1997 and at 15 other sites in 1995, 1996, and 1997 (Fig. 12) failed to produce speckled chub in the area of attempted introduction. Similar efforts at two sites on the lower Salt Fork River (Fig. 12) produced 27 speckled chub at one site and two at the other. If the species had been present at a detectability ($\underline{P}$) of 0.15, 19 site-visits (collection attempts) would be needed to conclude with 95% confidence that speckled chub were absent from the study area; 25 site-visits were made in this study, corresponding with a probability of 0.02 that the species was present at a detectability of 0.15 and went undetected as a result of sampling error.

The ANOVA revealed two statistically significant differences ($\alpha = 0.01$) between streams where _M. hyostoma_ was present and those where they were absent (Table VI). Mean depth was significantly lower ($\underline{P} < 0.01$) and pebble\cobble substrates were more abundant ($\underline{P} < 0.01$) in the Medicine Lodge and upper Salt Fork rivers than in the Cimarron and lower Salt Fork of rivers.

# DISCUSSION

The introduction of *M. hyostoma* upstream of Great Salt Plains Reservoir was either unsuccessful or resulted in a population that was undetectable. The former seems more likely, given the extent of sampling and the expected high reproductive potential of this small cyprinid. I was present during all visits and have had extensive experience sampling speckled chubs throughout the Arkansas River Basin (Luttrell, 1997). Further, all sampling focused specifically on main-channel habitats most likely to produce the species. Thus, it seems unlikely that the species was present and went completely undetected during 25 separate visits to sites in the study area.

In Iowa and Wisconsin, populations referable to *M. hyostoma* (D. Eisenhour, pers. comm.) apparently reproduce and die within 16 months of hatching (Starrett, 1951; Becker, 1983); Oklahoma populations are probably similar in life history. Thus, the individuals released in 1994, all of which were $\geq$ 1 year of age, probably would not have survived into 1995. If they had spawned in the first spring and summer after release, their progeny would have reached reproductive age by June 1995 (Starrett, 1951). If the introduction had been a success, the 1996 population would have included third-generation offspring from the original founders. Little is known about reproductive potential in speckled chub, but, with three years of successful reproduction, there probably would have been a detectable population. In Wisconsin, individual females can contain several hundred eggs (Becker, 1983), and Starrett (1951) observed that a limited population of speckled chub can produce a dense population by the following year, implying high reproductive potential. Further, within one year's time, a recolonizing population of *M. hyostoma* became sufficiently abundant that it was detected at 11 sites over a 191-km stretch of the Cimarron River in Oklahoma (Luttrell, 1997).

In a review of attempts to introduce small, short-lived species into areas of previous occurrence, in the western United States, Hendrickson and Brooks (1991) found that only about 26% of 406 attempts were successful (39% of 49 attempts with cyprinids). Reasons for failure were generally unknown, but marginal habitats and the presence of non-endemic predators and competitors were considered important factors. Effects of non-endemic species seems unlikely as an explanation for failure of my attempted introduction of speckled chub. All species found in the study area coexist with speckled chub elsewhere in the Arkansas River drainage (pers. observ.).

So far as is known, habitat requirements of speckled chub include pea-gravel substrata (Luttrell, 1997) and spring or summer floods for spawning purposes (Bottrell et al., 1964). My analysis indicated that pea-gravel is no less abundant in the area of attempted introduction than it is in riverine situations that consistently support *M. hyostoma*. Discharge records for the Medicine Lodge and Salt Fork of the Arkansas rivers (Fig. 13) indicate that insufficient flooding in 1994 may explain failure of the introduction of this short-lived species. However, the intensity of flooding needed for successful spawning of speckled chub is unknown.

Sampling points in the streams of attempted introduction were shallower than those in stream reaches that support *M. hyostoma* elsewhere in the Arkansas River drainage. A more detailed analysis (Luttrell, 1997) indicates that speckled chub select different depths depending on the location of preferred substratum, and, as just mentioned, preferred substratum does not seem to be a limiting factor in the area of attempted introduction. *Macrhybopsis hyostoma* was historically absent from upstream areas of the Arkansas River drainage, including the area of attempted introduction (Luttrell, 1997). Instead, the upstream areas once supported *M. tetranema*, a species that may have been better adapted to smaller riverine habitats. Thus, reintroduction of *M. tetranema* might have a greater chance of success.

It appears that there are only two extant populations of *M. tetranema*, one in the Ninnescah and Arkansas rivers of Kansas and the other in the South Canadian River in northeastern New Mexico and the Texas Panhandle (Luttrell, 1997; D. Eisenhour, pers. comm.). Should one or the other of these two populations be lost or further depleted, reintroduction of the species upstream of Great Salt Plains Reservoir could become a high priority goal for conservation of the species.

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TABLE VI. Back-transformed means and standard deviations of habitat variables for the upper and lower Salt Fork of the Arkansas (= Salt Fork), Cimarron, and Medicine Lodge rivers. Means with the same letters were not significantly different (Tukey's HSD; $\alpha = 0.01$). _ns_ = not significant (ANOVA; _P_ > 0.01). _n_ = number of seine-hauls.

| | Chub absent | | | | Chub present | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Medicine Lodge River ($n$ = 30) | | Upper Salt Fork ($n$ = 30) | | Lower Salt Fork ($n$ = 20) | | Cimarron River ($n$ = 70) | | | |
| Variables | $\bar{x}$ | SD | $\bar{x}$ | SD | $\bar{x}$ | SD | $\bar{x}$ | SD | F | P |
| Mean Depth (cm) | 15.24[a] | 5.24 | 14.96[a] | 12.25 | 29.31[b] | 14.47 | 35.12[b] | 20.33 | 34.71 | <0.001 |
| Velocity (cm/s) | 30.83 | 4.78 | 24.08 | 7.76 | 22.81 | 9.22 | 27.23 | 11.73 | 1.56 | ns |
| Compaction (cm) | 3.56[c] | 0.49 | 3.25[c] | 0.68 | 2.25 | 1.13 | 4.22[c] | 2.42 | 34.73 | <0.001 |
| Fines (%) | 0.00 | 0.00 | 9.67[d] | 6.69 | 12.75[d] | 10.94 | 6.64[d] | 11.12 | 8.21 | <0.001 |
| Small-sand (%) | 21.83[e] | 10.38 | 28.77[e] | 13.24 | 32.25[ef] | 36.22 | 48.14[f] | 27.74 | 16.64 | <0.001 |
| Coarse-sand (%) | 52.00 | 20.07 | 32.23[g] | 12.34 | 30.75[g] | 31.80 | 23.79[g] | 19.70 | 11.73 | <0.001 |
| Pea-sized gravel(%) | 20.50 | 14.88 | 25.00 | 16.97 | 19.25 | 26.37 | 19.57 | 22.82 | 2.12 | ns |
| Pebble\cobble (%) | 5.67[h] | 8.98 | 4.33[h] | 6.26 | 0.50[i] | 2.24 | 1.29[i] | 3.37 | 8.94 | <0.001 |
| Boulder (%) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.57 | 4.78 | 1.19 | ns |
| Bedrock (%) | 0.00 | 0.00 | 0.00 | 0.00 | 4.50 | 14.68 | 0.00 | 0.00 | 3.12 | ns |

Fig. 11. Historical distribution of speckled chub in the Salt Fork of the Arkansas River drainage (Luttrell, 1997). Salt Fork = Salt Fork of the Arkansas River; Medicine Lodge = Medicine Lodge River. Shaded circles = records of *M. tetranema*; black circles = records of *M. hyostoma*; squares = records of both species. Inset shows geographic location of study area.

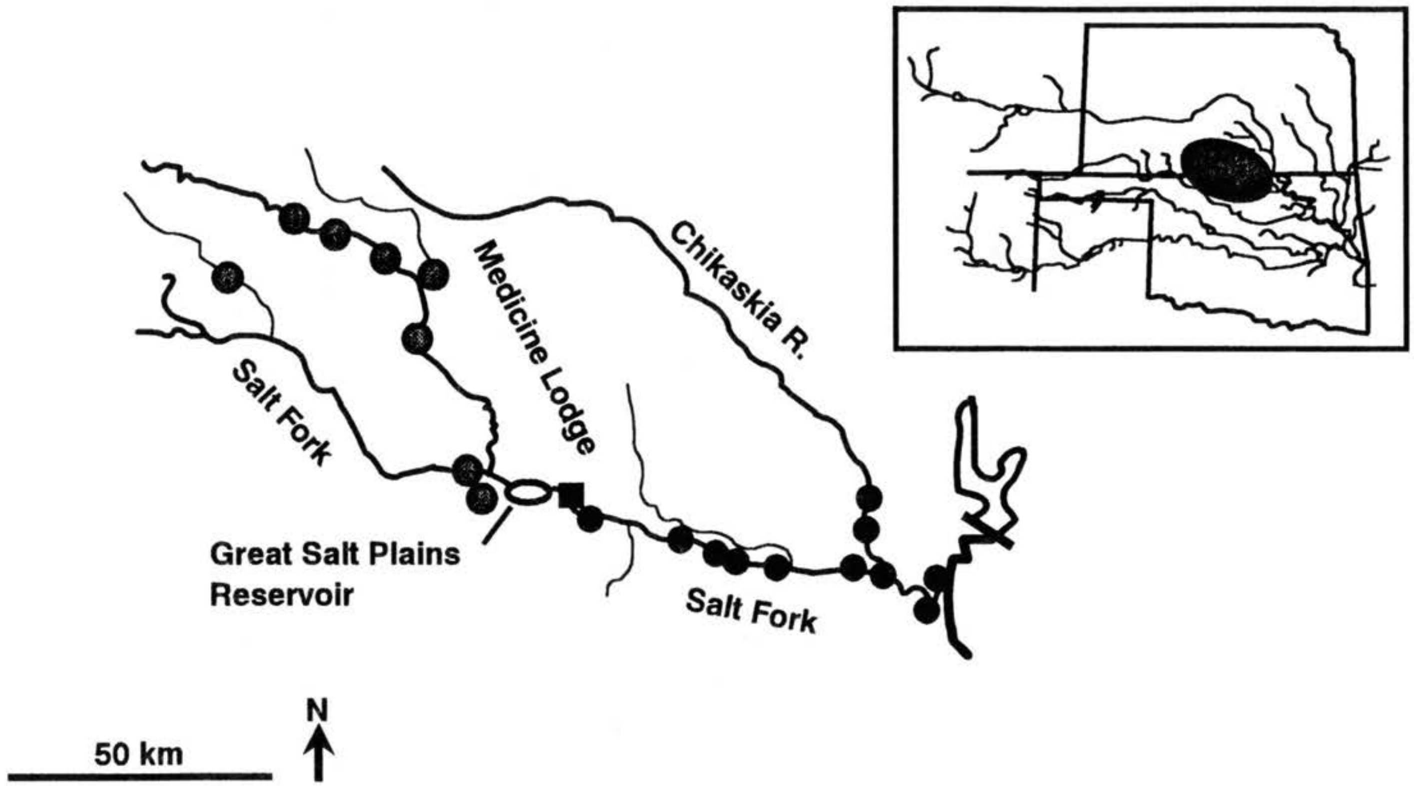
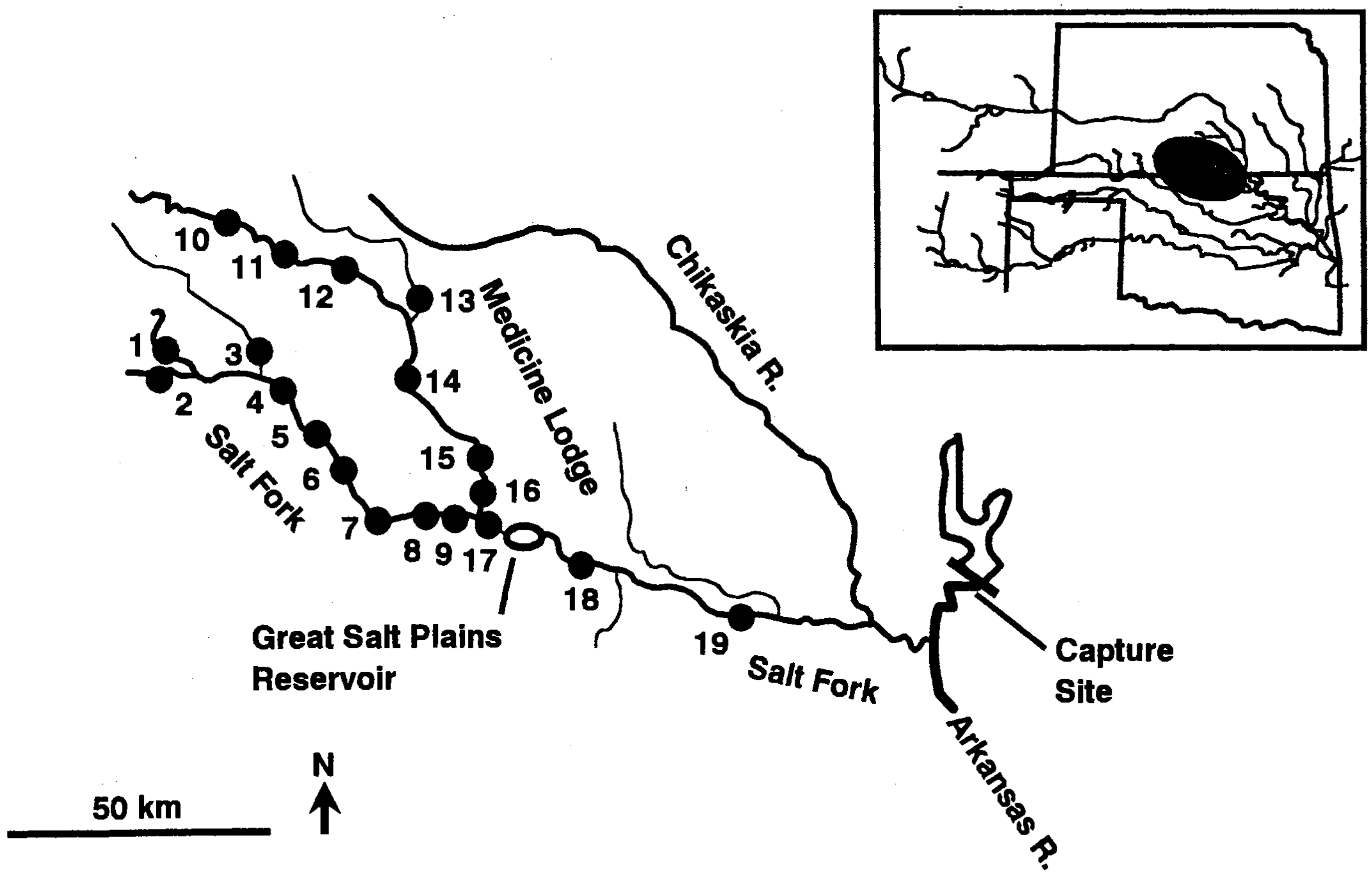

Chikaskia R.
Medicine Lodge
Salt Fork
Great Salt Plains
Reservoir
Salt Fork
50 km
N

Fig. 12. Map showing speckled chub capture site and release sites (7 and 12) and other study sites in the area. Habitat measurements were made at sites 7, 8, 9, 11, 12, 14, 18, and 19. Post-release seine-collections were made at sites 1-17 from 1994 through 1997. Specific site locality data are given in Appendix D. Inset shows approximate geographic location of study area.



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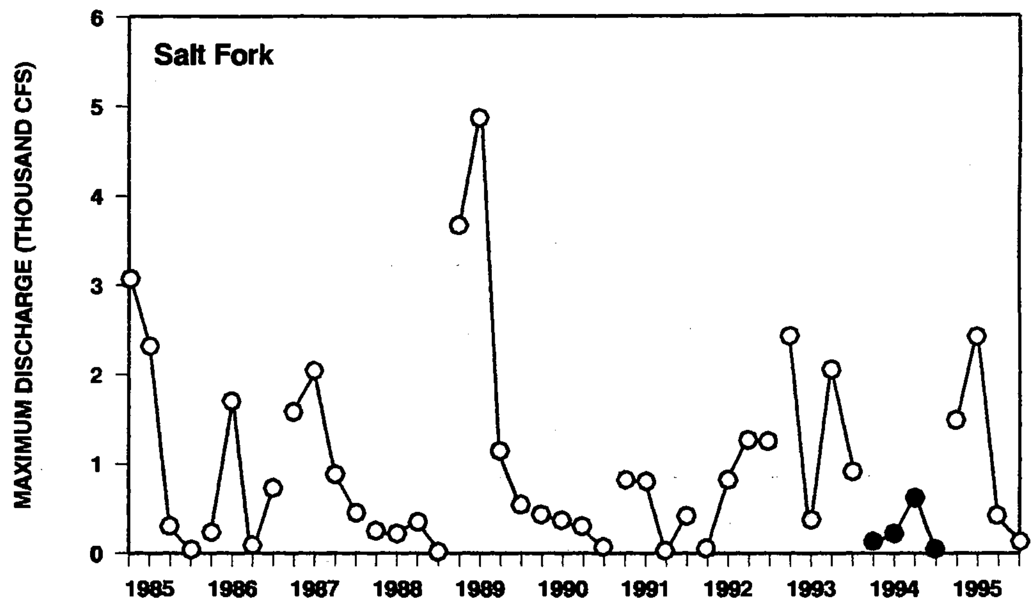
Medicine Lodge
Chikaskia R.
Salt Fork
Great Salt Plains
Reservoir
Salt Fork
Capture
Site
Arkansas R.
50 km
N

Fig. 13. Maximum daily discharges for the Salt Fork of the Arkansas River near Alva, Oklahoma (upper pane) and the Medicine Lodge River near Kiowa, Kansas (lower pane) in May-August of 1985-1995. Closed circles indicate flows during 1994.


Salt Fork
MAXIMUM DISCHARGE (THOUSAND CFS)
6
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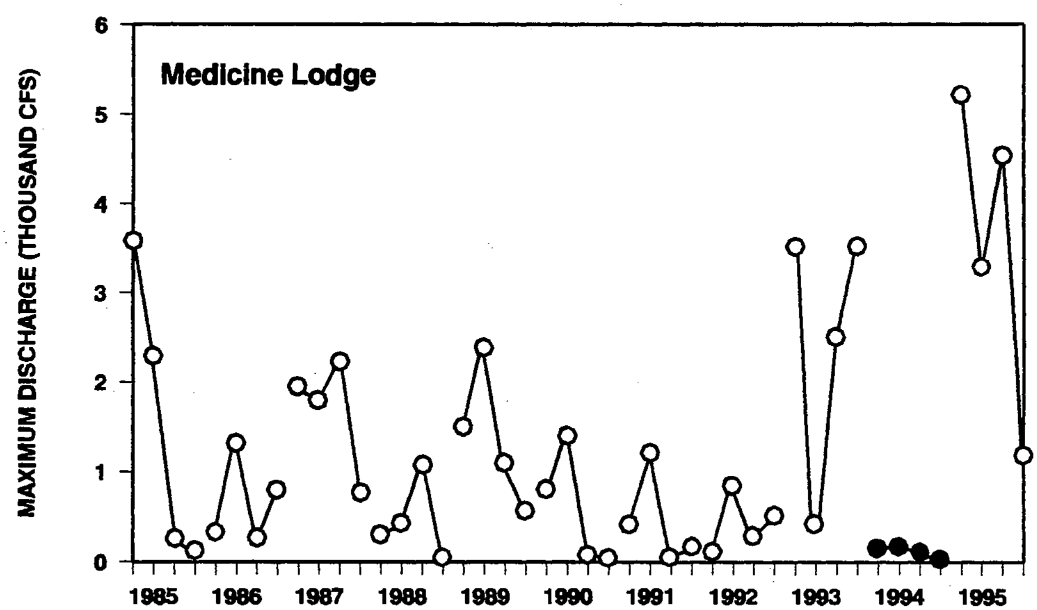
Medicine Lodge
MAXIMUM DISCHARGE (THOUSAND CFS)
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APPENDIXES

## APPENDIX A

Museum specimens of speckled chub examined from the Arkansas River Basin.

**Drainage**:
Species:
Locality.
Museum Number (number of specimens), date of collection.

**Arkansas River**:

Macrhybopsis tetranema:

KS: Finney Co., Arkansas R. S of Holcomb, T24S R33W S07 and S18. KU 2649 (2), 11 August 1952.

KS: Finney Co., Arkansas R. 0.25 to 0.50 mi. upstream of US Hwy. 83 bridge SW of Garden City. UMMZ 160431 (9), 25 July 1950.

KS: Finney Co., Arkansas R. USNM 194837 (4), 11 August 1952.

KS: Ford Co., Arkansas R., T27S R22W S32. KU 3938 (1), 13 June 1958.

KS: Barton Co., Arkansas R., T19S R12W S32. KU 2660 (2), 11 August 1952.

KS: Sedgwick Co., Arkansas R. at Wichita. USNM 41723 (4), 1889.

KS: Sedgwick Co., Arkansas R. 0.5 mi. upstream from US Hwy. 54 bridge in Wichita. KU 2004 (12), 26 January 1952.

KS: Sedgwick Co., Arkansas R., T27S R01E S18. KU 2027 (4), 1 March 1952.

KS: Sumner Co., Arkansas R. at Oxford. UMMZ 122162 (1), 29 June 1926.

KS: Sumner Co., Arkansas R. at diversion dam 2.0 mi. N and 0.5 mi. E of Oxford, T31S R02E S36. UMMZ 67822 (1), 29 June 1925. KU 21744 (1), 5 August 1986. KU 23094 (4), 13 July 1992. OSUS 25309 (5), 22 July 1992. OSUS 26319 (8), 14 June 1993.

Macrhybopsis hyostoma:

KS: Sumner Co., Arkansas R. 2.5 mi. N and 0.5 mi. E of Oxford near mouth of Ninnescah R. UMMZ 67816 (1), 29 June 1925.

KS: Sumner Co., Arkansas R. 2.0 mi. N and 0.5 mi. E of Oxford, T31S R02E S36. KU 21704 (1), 29 July 1984.

KS: Cowley Co., Arkansas R., T34S R03E S22. KU 3668 (1), 25 August 1956.

OK: Osage Co., Arkansas R. E side of Kaw Reservoir spillway, T26N R03E S25. OSUS 26589 (3), 11 July 1993. OSUS 26784 (143), 26 May 1994.

OK: Osage Co., Arkansas R. near Ponca City, T26N R02E S35. OSUS 19321 (3), 11 June 1980. OSUS 26691 (2), 11 June 1980. OSUS 26704 (1), 2 October 1988. OSUS 26696 (1), 21 June 1991. OSUS 27020 (132), 9 July

1991. OSUS 26673 (2), 26 July 1991. OSUS 25521 (4), 6 October 1992.

OK: Noble Co., Red Rock Cr. 12.0 mi. N of Perry and 0.5 mi. W of US Hwy. 77. OSUS 4017 (1), 18 February 1950.

OK: Osage Co., Salt Cr. at Fairfax. OSUS 9053 (1), 6 March 1975.

OK: Pawnee Co., Arkansas R. at Turkey Island. UMMZ 110885 (3), 7 July 1934.

OK: Pawnee/Osage Co., Arkansas R. near Ralston. UMMZ 113372 (21), 11 July 1936.

OK: Pawnee Co., Arkansas R. at Ralston, T23N R05E S01. OSUS 19424 (3), 13 October 1979. OSUS 19420 (6), 5 April 1980. OSUS 19335 (3), 14 September 1985. OSUS 19939 (1), 13 October 1990. OSUS 25830 (1), 6 October 1992.

OK: Pawnee Co., Arkansas R. 5.0 mi. below Blackburn, T22N R07E S11 and S14. OSUS 5275 (1), 30 December 1956.

OK: Pawnee Co., Arkansas R. at pumping station G, T23N R03E S16. OSUS 7957 (2), 15 February 1975. OSUS 9203 (2), 11 April 1975.

OK: Pawnee Co., Arkansas R. at Greasy Cr. station A, T23N R03E S24. OSUS 9716 (72), 6 December 1975.

OK: Pawnee Co., Arkansas R. 6 mi. WNW of Cleveland, T22N R07E S32. OSUS 23635 (1), 7 February 1970. OSUS 23624 (16), 7 February 1970. OSUS 23630 (5), 7 March 1970. OSUS 23622 (6), 27 February 1976.

OK: Tulsa Co., Arkansas R. near Keystone, T19N R10E S04. OKMNH 39017 (66), 9 April 1960.

OK: Tulsa Co., Arkansas R. at Hwy. 51 and 97 bridge in Sand Springs, T19N R11E S14. OSUS 19561 (1), 5 July 1983. OSUS 26601 (7), 11 September 1993.

OK: Tulsa Co., Arkansas R. at Bixby, T17N R13E S14. OSUS 26682 (5), 29 August 1986.

OK: Tulsa Co., Arkansas R. at US Hwy. 64 bridge near Bixby, T17N R13E S13. OSUS 26609 (2), 11 September 1993.

OK: Tulsa Co., Arkansas R. N of Bixby, T17N R13E S12. OSUS 19562 (9), 21 August 1983.

OK: Tulsa Co., Arkansas R. at Jenks Bridge. OSUS 12911 (1), 26 April 1986.

OK: Muskogee Co., Arkansas R. NE of Haskell, T16N R16E S32. OSUS 26695 (1), 24 August 1980. OSUS 26713 (3), 2 July 1991.

OK: Muskogee Co., Arkansas R. at Muskogee, T15N R19E S21. OSUS 26698 (1), 5 June 1988. OSUS 26770 (1), 14 May 1993.

OK: Sequoyah Co., Arkansas R. at WD Mayo Lock and Dam #14. OSUS 11738

(42), 15 November 1963.

OK: Le Flore Co., Arkansas R. below WD Mayo Lock and Dam #14, T10N R26E S34. OSUS 26769 (1), 15 May 1993.

AR: Sebastian Co., Arkansas R. at Fort Smith. USNM 36374 (4), July-September 1884.

AR: Pope Co., Arkansas R. at Dardanelle. TU 10403 (1), 11 May 1955. TU 14879 (1), 11 May 1955. TU 39670 (2), 22 April 1961. OSUS 7224 (92), 15 November 1963. OSUS 7881 (15), 15 November 1963.

AR: Yell Co., Arkansas R. at Dardanelle. TU 15645 (7), 2 May 1955. TU 15470 (4), 18 May 1957.

AR: Yell Co., Arkansas R., rocks at Dardanelle. TU 13907 (6), 29 July 1955.

AR: Arkansas Co., Arkansas R. at Pendalton's Ferry. TU 22426 (211), 23 October 1959.

*Macrhybopsis tetranema* and *Macrhybopsis hyostoma*:

KS: Sumner Co., Arkansas R. below Oxford Mill Diversion Dam. KU 8311 (15 *M. tetranema* and 12 *M. hyostoma*), 12 June 1964.

OK: Tulsa Co., Arkansas R. at Keystone. OKMNH 39032 (1 *M. tetranema* and 2 *M. hyostoma*), 3 October 1960.

**Ninnescah River drainage:**

*Macrhybopsis tetranema*:

KS: Kingman Co., South Fork of the Ninnescah R. at Kingman City Park, T28S R07W S05. OSUS 25292 (14), 23 July 1992. OSUS 26275 (2), 15 June 1993.

KS: Kingman Co., South Fork of the Ninnescah R. 3.5 mi. S and 1.5 mi. W of Cheney, T28S R05W S25 and S26. KU 8534 (24), 22 July 1964.

KS: Sedgwick Co., North Fork of the Ninnescah R. 3.5 mi. W of Garden Plain at old US Hwy. 54 crossing, T27S R04W S33. KU 8168 (1), 30 August 1963.

KS: Sedgwick Co., North Fork of the Ninnescah R. 3.5 mi. W of Garden Plain at old US Hwy. 54 crossing, T27S R04W S33. OSUS 12537 (12) and KU 8542 (107), 22 July 1964.

KS: Sumner Co., Ninnescah R. 6 mi. NW of Oxford. ANSP 104506 (1), 15 May 1933.

*Macrhybopsis hyostoma*:

KS: Sumner Co., Ninnescah R. on Kansas Turnpike 14.7 mi. S of Wichita interchange. KU 8285 (1), 26 July 1964.

**Salt Fork of the Arkansas River drainage:**

**Chikaskia River:**

Macrhybopsis hyostoma:

OK: Kay Co., Chikaskia R., T26N R01W S25 and S36. OSUS 54 (1), 16 March 1940.

OK: Kay Co., Chikaskia R. SE of Blackwell at old iron-bridge, T27N R01W S36. OSUS 25546 (1), 11 July 1978. OSUS 26694 (3), 19 July 1980. OSUS 26703 (1), 11 September 1982. OSUS 25544 (4), 25 August 1984. OSUS 25543 (15), 5 July 1985. OSUS 26697 (1), 9 August 1985. OSUS 25545 (2) and OSUS 26711 (4), 16 July 1986. OSUS 19085 (4), 25 May 1988. OSUS 27509 (1), 25 September 1994.

**Medicine Lodge River:**

Macrhybopsis tetranema:

KS: Barber Co., Medicine Lodge R. at Sun City. KU 3899 (13), 18 August 1957.

KS: Barber Co., Medicine Lodge R. 0.75 mi. S of Lake City. UMMZ 126823 (1), 12 November 1938.

KS: Barber Co., Medicine Lodge R. 5.0 mi. NW of Medicine Lodge. UMMZ 126802 (1), 12 November 1938.

KS: Barber Co., Elm Cr. at Medicine Lodge, T32S R12W S12. KU 1803 (3), 21 July 1951.

KS: Barber Co., Medicine Lodge R., T33S R11W S20 and S21. KU 3932 (4), 12 June 1958.

**Salt Fork of the Arkansas River:**

Macrhybopsis tetranema:

KS: Comanche Co., Mule Cr., T32S R16W S10. KU 6422 (5), 29 August 1960.

KS: Comanche Co., Mule Cr. 16.0 mi. E of Coldwater. KU 8574 (5), 18 July 1964.

OK: Alfalfa Co., Salt Fork of the Arkansas R. 5.0 mi. N of Cherokee. UMMZ 109387 (10), 21 June 1930. OKMNH 15555 (18), 21 June 1930.

OK: Alfalfa Co., Pond 3.5 mi. E of Cherokee. UMMZ 109386 (3), 13 June 1930.

OK: Alfalfa Co., Salt Fork of the Arkansas R. 7.0 mi. E and 2.0 mi. N of Ingersoll. UMMZ 80467 (8), 11 July 1926. OKMNH 6274 (6), 11 July 1926.

Macrhybopsis hyostoma:

OK: Alfalfa Co., Salt Fork of the Arkansas R. 3.0 mi. E and 5 mi. N of Jet. OSUS 1869 (2), OSUS 1870 (13), and TU 2265 (4), 16 August 1947.

OK: Grant Co., Salt Fork of the Arkansas R. 2.25 mi. N of Nash, T26N R08W S27. OSUS 26715 (1), 4 June 1980. OSUS 19586 (52), 24 July 1984. OSUS 18200 (2), 20 July 1989. OSUS 26709 (1), 5 July 1990. OSUS 19726 (1), 23 May 1991. OSUS 26856 (2), 26 July 1994.

OK: Grant Co., Salt Fork of the Arkansas R. at E edge of Pond Creek, T25N R06W S01. OSUS 18061 (19), 20 July 1989. OSUS 19152 (3), 10 August 1990. OSUS 25432 (1), 27 July 1992.

OK: Grant Co., Salt Fork of the Arkansas R. 3.0 mi. W and 0.75 mi. N of Salt Fork, T25N R04W S01. OSUS 25430 (1), 27 July 1992.

OK: Grant Co., Salt Fork of the Arkansas R. 0.50 mi. N of Salt Fork at Hwy. 74 bridge, T25N R04W S13 and S14. OSUS 26843 (13), OSUS 26845 (8), OSUS 26849 (3), OSUS 26851 (2), and OSUS 26852 (1), 20 July 1994.

OK: Grant Co., Salt Fork of the Arkansas R. S of Lamont at old Hwy. 74 crossing, T25N R03W S06. OSUS 18112 (1), 20 July 1989. OSUS 19143 (5), 10 August 1990. OSUS 25428 (2), 27 July 1992.

OK: Kay Co., Salt Fork of the Arkansas R. at Hwy. 77 bridge S edge of Tonkawa, T25N R01W S04. OSUS 25829 (1), 6 October 1992.

OK: Kay Co., Salt Fork of the Arkansas R. at confluence with the Chikaskia R., T25N R01E S19. OSUS 25831 (1), 6 October 1992.

OK: Noble Co., Salt Fork of the Arkansas R. 5.0 mi. NE of Marland. UMMZ 127283 (12), 24 August 1939.

OK: Kay Co., Salt Fork of the Arkansas R. 8.0 mi. S of Ponca City at Hwy. 40 bridge. OSUS 11807(6), 26 February 1961.

OK: Noble Co., Salt Fork of the Arkansas R. S of Ponca City and 1.0 mi. E of Hwy. 177 bridge, T24N R02E S10. TU 13840 (129), 1 September 1955 and OSUS 18089 (94), 18 July 1989.

OK: Kay Co., Salt Fork of the Arkansas R. S of Ponca City near confluence with Arkansas R. UMMZ 127199 (36), 24 August 1939.

Macrhybopsis tetranema and Macrhybopsis hyostoma:

OK: Alfalfa Co., Salt Fork of the Arkansas R. below Great Salt Plains Dam. OKMNH 29157 (11 M. tetranema and 5 M. hyostoma), 26 March 1949.

**Cimarron River drainage:**

Macrhybopsis tetranema:

KS: Seward Co., Cimarron R. on XI Ranch SE of Arkalon, T34S R31W S25. UMMZ 161988 (6), 19 August 1951.

KS: Meade Co., Crooked Cr. at Borcher's pasture. UMMZ 176842 (7), 26

June 1952. UMMZ 176849 (5), 1 August 1952.

KS: Meade Co., Crooked Cr. 8.0 mi. S and 2.25 mi. W of Meade. UMMZ 160418 (1), 24 July 1950.

OK: Harper Co., Cimarron R., T29N R26W S23. OKMNH 32444 (4), 23 June 1963.

OK: Major Co., Cimarron R. OKMNH 33793 (2), 3 May 1962.

OK: Major Co., Main Cr. WNW of Bouse Junction. OKMNH 33800 (2), 3 May 1962.

OK: Major Co., Cimarron R. 3.0 mi. S of Cleo Springs. UMMZ 108888 (10) and OKMNH 15551 (32), 18 July 1928.

OK: Major Co., Eagle Chief Cr. 0.25 mi. NW of Cleo Springs. OKMNH 15552 (6) and UMMZ 108889 (3), 18 July 1928.

OK: Major Co., Eagle Chief Cr. near Cleo Springs. OKMNH 15663 (25) and UMMZ 109388 (10), 27 June 1930.

OK: Major Co., Eagle Chief Cr. 3.0 mi. S of Cleo Springs. OKMNH 15662 (76) and UMMZ 109389 (26), 28 June 1930.

OK: Logan Co., Cimarron R. below mouth of Skeleton Creek. UMMZ 127185 (57), 4 August 1939.

OK: Logan Co., Skeleton Cr. N of Guthrie. OSUS 1455 (7), 24 June 1939.

OK: Logan Co., Cimarron R. N of Coyle. UMMZ 109059 (8), 25 July 1929.

OK: Logan Co., Cimarron R. OKMNH 15664 (18), 25 July 1929.

OK: Logan Co., Cimarron R. OKMNH 15666 (13), 25 July 1929.

OK: Payne Co., Cimarron R. 1.0 mi. W of Perkins bridge. UMMZ 193731 (16), 1941.

OK: Payne Co., Cimarron R. 13.0 mi. S of Stillwater. UMMZ 210636 (40), 10 February 1940.

OK: Payne Co., Wild Horse Cr. at Hasting's Farm 4.0 mi. W of Perkins. OSUS 1419 (2) and OSUS 1860 (2), 9 April 1932.

OK: Payne Co., Cimarron R. near Hasting's Farm 4.0 mi. W of Perkins. OSUS 1857 (6), 10 May 1932.

OK: Payne Co., Cimarron R. near Perkins. OSUS 1858 (6), 19 November 1933. OSUS 1859 (8), 28 April 1934.

OK: Payne Co., Cimarron R. SE of Perkins. OSUS 1856 (5), 9 May 1932. UMMZ 108313 (28), 4 April 1932.

OK: Payne Co., Cimarron R. 9.0 mi. S and 2 mi. E of Stillwater. CU 24435 (76), 14 March 1936.

OK: Payne Co., Cimarron R. 6.3 mi. S of Stillwater. OSUS 1465 (9), 10

February 1939.

OK: Payne Co., Cimarron R. at mouth of Stillwater Cr. OSUS 1447 (7), 10 February 1939.

OK: Payne Co., Tributary of Stillwater Cr. at bridge above confluence with Stillwater Cr. OSUS 26753 (12), 28 February 1948.

OK: Payne Co. Cimarron R. 4 mi. E of Ripley. UMMZ 127165 (44), 12 November 1939.

OK: Creek Co. Cimarron R., T19N R07E S27. OKMNH 38951 (13), 7 February 1960.

<u>Macrhybopsis</u> <u>hyostoma</u>:

OK: Major Co., Cimarron R. 2.5 mi. S of Cleo Springs at Hwy. 8 bridge - mouth of Eagle Chief Cr., T22N R12W S23. OSUS 27505 (90), 14 July 1995.

OK: Major Co., Cimarron R. WSW of Ames on county road, T20N R10W S10 and S15. OSUS 27506 (3), 21 July 1995.

OK: Kingfisher Co., Cimarron R. 8.5 mi. E of Okeene at Hwy. 51 bridge, T19N R09W S16. OSUS 27507 (35), 14 August 1995.

OK: Kingfisher Co., Cimarron R. 2.5 mi. W of Dover at old iron-bridge, T17N R07W S05. OSUS 26588 (1), 17 August 1993. OSUS 26853 (1), OSUS 26854 (3), and OSUS 26855 (1), 27 July 1994.

OK: Logan Co., Cimarron R. 5.0 mi. S of Crescent at Hwy. 74 bridge, T16N R04W S02 and S03. OSUS 26603 (2), 17 August 1993.

OK: Logan Co., Cimarron R. 2.5 mi. N of Guthrie at Hwy. 77 bridge, T17N R02W S28 and S29. OSUS 26604 (29), 17 August 1993. OSUS 26879 (1) and OSUS 26839 (26), 24 June 1994.

OK: Payne Co., Cimarron R. 0.75 mi. S of Perkins at Hwy. 177 bridge, T17N R03E S07. OSUS 26595 (18), 13 July 1993.

OK: Payne Co., Cimarron R. at 6.75 mi. E and 0.75 mi. N of Perkins at Hwy. 33 bridge, T18N R04E S31. OSUS 26607 (16), 12 August 1993.

OK: Payne Co., Cimarron R. at mouth of Stillwater Cr. (Ripley Bridge), T18N R04E S19. OSUS 26251 (1), 7 July 1993. OSUS 26597 (8), 12 August 1993. OSUS 26875 (1), OSUS 26872 (2), OSUS 26873 (1), OSUS 26878 (2), OSUS 26874(1), OSUS 26877 (1), and OSUS 26876 (2), 23 June 1994. OSUS 26840 (1) and OSUS 26841 (1), 4 August 1994.

OK: Payne Co., Cimarron R. 4.0 mi. NW of Cushing, T18N R04E S12. OKMNH 51562 (1), 15 September 1992.

OK: Payne Co., Cimarron R. 4.75 mi. N of Cushing at Hwy. 18 bridge, T18N R05E S10. OSUS 26261 (1), 7 July 1993.

OK: Payne Co., Cimarron R. 1.0 mi. S of Yale, T19N R05E S25. OSUS 26591 (4), 24 June 1993.

OK: Creek Co., Cimarron R. 1.0 mi. S and 1.0 mi. W of Oilton, T18N R07E S08. OKMNH 51563 (3), 15 September 1992. OSUS 26260 (1), 7 July 1993.

OK: Creek Co., Cimarron R. 0.5 mi. N of Oilton at OK Hwy. 99 Bridge, T19N R07E S28. OSUS 26257 (11), 7 July 1993.

Macrhybopsis hyostoma and Macrhybopsis tetranema:

OK: Logan Co., Cimarron R. N of Guthrie on US 77, T17N R02W S29. OKMNH 33985 (1 M. hyostoma and 5 M. tetranema), 3 May 1965.

OK: Payne Co., Cimarron R. at Ripley Bridge. USNM 161636 (8 M. hyostoma and 40 M. tetranema), 26 April 1935.

OK: Pawnee Co., Cimarron R., T20N R10E S31. OKMNH 39025 (10 M. hyostoma and 2 M. tetranema), 9 August 1960.

**Canadian River drainage:**

**Canadian River:**

Macrhybopsis hyostoma:

OK: Haskell/Muskogee Co., Canadian R. at Hwy. 2 bridge N edge of Whitefield, T09N R20E S07. OSUS 26360 (10), 27 July 1993.

OK: Haskell/Muskogee Co., Canadian R. 0.50 mi. N of Whitefield, T09N R19E S12. OSUS 26712 (1), 29 July 1985.

OK: Haskell Co., Canadian R., T10N R18E S28. OKMNH 35019 (8), 10 July 1962.

OK: Haskell Co., Canadian R. 0.25 mi. E of Whitefield. OKMNH 36236 (14), 23 August 1962.

OK: McIntosh Co., Canadian R., T10N R16E S24. OKMNH 36301 (3), 1 March 1959.

OK: McIntosh Co., Canadian R. between Standing Rock and Broken Cr. OKMNH 36223 (42), 23 August 1962.

OK: McIntosh Co., Canadian R., T10N R17E S34. OKMNH 36110 (11), 16 August 1962.

**Deep Fork River:**

Macrhybopsis hyostoma:

OK: Okmulgee Co., Deep Fork R. W of Hoffman. OKMNH 36072 (2), 15 August 1962.

OK: McIntosh Co., Deep Fork R. 3 mi. from Richardsville. OKMNH 36211 (1), 22 August 1962.

**North Canadian River:**

Macrhybopsis tetranema:

OK: Texas Co., Coldwater Cr. 8 mi. SE of Guymon. UMMZ 80431 (18), 1 July 1926.

OK: Texas Co., North Canadian R. due N of Guymon. UF 7912 (8), KU 2131 (3), and CU 17903 (5), 29 May 1949.

OK: Texas Co., Palo Duro Cr. OSUS 4124 (6), 29 May 1949.

OK: Harper Co., Beaver Cr. (Beaver R.) N of Laverne. OSUS 1712 (1), 17 June 1947.

OK: Woodward Co., North Canadian R. 5.0 mi. E and 1.0 mi. N of Woodward. UMMZ 108887 (51), 13 July 1928.

OK: Woodward Co., North Canadian R. near Woodward, T23N R20W S25. OSUS 19235 (1), 14 July 1982

Macrhybopsis hyostoma:

OK: McIntosh Co., North Canadian R. above confluence with the Deep Fork R. OKMNH 34533 (13), 15 June 1962.

OK: McIntosh Co., North Canadian R., T09N R17E S05. OKMNH 35090 (11), 13 July 1962.

OK: McIntosh Co., North Canadian R., T11N R14E S28. OKMNH 34815 (2), 29 June 1962.

**South Canadian River:**

Macrhybopsis tetranema:

NM: Quay Co., South Canadian R. at Collins Ranch, T13N R35E S01. OSUS 18891 (1), 11 July 1990.

NM: Quay Co., South Canadian R. 6.0 mi. E of Logan, T15N R34E S03. OSUS 18673 (5), 9 July 1990.

NM: Quay Co., South Canadian R. N of Logan at US Hwy. 54 bridge. OSUS 18679 (4), 9 July 1990.

NM: Quay Co., Revuelto Cr. at Hwy. 39 bridge S of Logan. OSUS 18832 (4), 10 July 1990.

TX: Oldham Co., South Canadian R. 3 mi. E of Tascosa. OSUS 3125 (2), 24 July 1949.

TX: Oldham Co., South Canadian R. 12.0 mi. S of Channing at Hwy. 385 bridge (near Boy's Ranch). OSUS 18837 (114), 11 July 1990 and OSUS 27515 (37), 11 July 1995.

TX: Potter Co., South Canadian R. 15.0 mi. N of Amarillo at Hwy. 287 and 87 bridge. OSUS 18703 (16), 9 July 1990.

TX: Potter Co., South Canadian R. 18.0 mi. N of Amarillo at Hwy. 287 bridge. TU 99165 (209), 25 August 1976.

TX: Roberts Co., South Canadian R. at Hwy. 70 bridge. TU 20135 (4), 2

June 1959.

TX: Hemphill Co., South Canadian R. 8.6 mi. off farm road 2266. TU 20140 (17), 1 June 1959.

OK: Dewey Co., South Canadian R. 4.0 mi. SW of Taloga. UMMZ 108886 (10), 11 July 1928.

OK: Dewey Co., South Canadian R. OKMNH 15550 (1), 12 July 1928.

OK: Cleveland/McClain Co., South Canadian R. near Newcastle. KU 2328 (2), 15 April 1952.

OK: McClain Co., South Canadian R. at Purcell. UMMZ 110081 (5), 28 July 1932.

OK: McClain Co., South Canadian R. OKMNH 15668 (7), 28 July 1932.

Macrhybopsis hyostoma:

OK: Hughes Co., South Canadian R., T07N R12E S20. OKMNH 35332 (3), 27 July 1962.

OK: Hughes Co., South Canadian R., T06N R10E S22. OSUS 26777 (1), 3 October 1992.

OK: Pittsburg Co., South Canadian R. 4 mi. N of Canadian on US Hwy. 69. KU 5952 (3), 29 March 1965.

OK: McIntosh Co., South Canadian R., T09N R16E S28. OKMNH 35103 (9), 13 July 1962.

OK: McIntosh Co., South Canadian R. OKMNH 15553 (1), 29 June 1929.

**Illinois River drainage:**

Macrhybopsis hyostoma:

OK: Sequoyah Co., Illinois R., T12N R21E S20 and S21. OSUS 2417 (7), 24 August 1946.

OK: Sequoyah Co., Illinois R. near Gore, T13N R21E S27. OSUS 27508 (1), 1 October 1995.

# APPENDIX B

Arkansas River Basin sites sampled for speckled chub from 1991 through 1997.

**Drainage**, no. of collections no. of sites:
State: County, Stream and location. Date(s) of collection.

**Arkansas River**, 26 collections at 20 sites:

CO: Bent Co., Arkansas R. immediately downstream from John Martin Reservoir stilling basin. 27 May 1993.

CO: Prowers Co., Arkansas R. at Hwy. 50 bridge N of Lamar. 27 May 1993.
KS: Hamilton Co., Arkansas R. 0.75 mi. S of Coolidge, T23S R43W S26. 27 May 1993.

KS: Kearny Co., Arkansas R. at Amazon Diversion Dam 3 mi. S and 10.5 mi. W of Lakin, T25S R38W S12. 26 May 1993.

KS: Finney Co., Arkansas R. 0.75 mi. S of Holcomb, T24S R34W S07. 26 May 1993.

KS: Barton Co., Arkansas R. at Dundee Diversion Dam 1 mi. S of Dundee, T20S R14W S20. 26 May 1993.

KS: Sedgwick Co., Arkansas R. at 47th Street bridge in Wichita, T28S R01E S15. 15 June 1993.

KS: Sumner/Sedgwick Co., Arkansas R. at Hwy. 53 bridge W edge of Mulvane, below bridge is Sumner Co. - T30S R01E S01, above bridge is Sedgwick Co. - T29S R02E S31. 22 July 1992 and 15 June 1993.

KS: Sumner Co., Arkansas R. at Oxford Mill Diversion Dam 2 mi. N and 0.5 mi. E of Oxford, T31S R02E S36. 22 July 1992, 14 June 1993, 15 June 1993, and 26 October 1995.

KS: Cowley Co., Arkansas R. at US Hwy. 166 bridge W edge of Arkansas City, T34S R03E S35. 3 August 1994.

OK: Osage Co., Arkansas River at Kaw Reservoir Spillway, T26N R03E S25. 17 May 1994 and 20 May 1995.

OK: Kay/Osage Co., Arkansas R. at Hwy. 60 bridge E edge of Ponca City, T25N R02E S02. 6 October 1992 and 3 June 1994.

OK: Noble Co., Red Rock Cr. 11 mi. N and 0.75 mi. W of Perry, T23N R01W S15 and S22. 28 July 1992.

OK: Pawnee/Osage Co., Arkansas R. at Hwy. 18 bridge near Ralston, T23N R05E S01. 6 October 1992.

OK: Tulsa Co., Keystone Reservoir in Pawnee Cove, T19N R10E S06. 13 August 1993.

OK: Creek Co., Keystone Reservoir in Salt Creek Arm, T19N R09E S11 and S14. 13 August 1993.

OK: Pawnee Co., Keystone Reservoir in Apalachia Bay, T20N R09E S24. 13 August 1993.

OK: Tulsa Co., Arkansas R. at Hwy. 51 and 97 bridge in Sand Springs, T19N R11E S14. 11 September 1993.

OK: Tulsa Co., Arkansas R. at Hwy. 64 bridge in Bixby, T17N R13E S13. 11 September 1993.

OK: Muskogee/Wagoner Co., Arkansas R. at Hwy. 104 bridge 2 mi. E of Haskell, T16N R16E S32. 11 September 1993.

**Ninnescah River,** 14 collections at 9 sites:

KS: Pratt Co., South Fork of the Ninnescah R. at S edge of Pratt, T28S R13W S02 and S03. 23 July 1992.

KS: Pratt Co., South Fork of the Ninnescah R. at Hwy. 54 bridge 4 mi. E of Pratt, T27S R12W S33. 15 June 1993.

KS: Kingman Co., South Fork of the Ninnescah R. at the Kingman City Park, T28S R07W S05. 23 July 1992, 21 May 1993, 15 June 1993, and 26 October 1995.

KS: Kingman Co., South Fork of the Ninnescah R. at Hwy. 54 bridge 3 mi. E of Cunningham, above bridge - T27S R10W S36, and below bridge - T28S R10W S01. 23 July 1992 and 15 June 1993.

KS: Sedgwick Co., South Fork of the Ninnescah R. 1.25 mi. S of Cheney, T28S R04W S20 and S21. 22 July 1992 and 15 June 1993.

KS: Reno Co., North Fork of the Ninnescah R. at Hwy. 17 bridge 13.5 mi. S of Hutchinson, T25S R06W S26. 21 May 1993.

KS: Sedgwick Co., North Fork of the Ninnescah R. 3 mi. E and 2.25 mi. S of Cheney, T28S R04W S25 and S26. 22 July 1992.

KS: Sedgwick Co., Ninnescah River SW of Clearwater, T29S R02W S26 and S27. 22 July 1992.

KS: Sumner Co., Ninnescah R. 2 mi. S of Belle Plaine, T31S R01E S11 and S12. 22 July 1992.

**Salt Fork of the Arkansas River drainage:**

**Chikaskia River,** 70 collections at 39 sites:

KS: Kingman Co., Chikaskia R. at Hwy. 42 bridge 1.75 mi. W of Spivey, T30S R08W S09. 23 July 1992 and 21 May 1993.

KS: Harper Co., Chikaskia R. 4 mi. N and 1.5 mi. E of Danville, T31S R05W S16 and S21. 15 June and 6 July 1992.

KS: Harper Co., Sandy Cr. near confluence with Chikaskia R., T31S R05W S22. 15 June and 6 July 1992.

KS: Sumner Co., Argonia Cr. 0.75 mi. W of Argonia, T32S R04W S17 and S20. 15 June and 6 July 1992.

KS: Sumner Co., Beaver Cr. 3 mi. E of Milan, T32S R03W S15 and S22. 15 June and 6 July 1992.

KS: Sumner Co., Beaver Cr. at spring outlet near railroad bridge, T32S R03W S15. 6 July 1992.

KS: Sumner Co., Sand Cr. 2 mi. W of Milan, T32S R04W S13 and S24. 15 June and 6 July 1992.

KS: Sumner Co., West Prairie Cr. at Hwy. 160 bridge near Mayfield, T32S R02W S07 and S18. 15 June and 6 July 1992.

KS: Sumner Co., West Prairie Cr. 1 mi. W of Mayfield, T32S R02W S17 and S20. 15 June 1992.

KS: Sumner Co., Chikaskia R. near Drury ca. 0.75 mi. downstream of low-water dam, T35S R02W S01. 6 and 19 July 1992.

KS: Sumner Co., Chikaskia R. at Drury immediately downstream of low-water dam, T35S R02W S01. 17 June 1993.

KS: Harper Co., Rock Cr. SE of Anthony, T34S R06W S04 and S09. 19 July 1992 and 20 May 1993.

KS: Harper Co., Unnamed Cr. SE of Anthony, T34S R06W S05 and S08. 19 July 1992 and 20 May 1993.

KS: Harper Co., Silver Cr. NW of Bluff City, T34S R06W S01 and S12. 19 July 1992 and 20 May 1993.

KS: Harper Co., Baehr Cr. 1 mi. N of Bluff City, T34S R05W S09 and S16. 19 July 1992 and 20 May 1993.

KS: Harper Co., Spring Branch 2 mi. E of Bluff City, T34S R05W S14 and S23. 19 July 1992 and 20 May 1993.

KS: Harper Co., Bluff Cr. at Hwy. 2 and 14 bridge 2.5 mi. W of Anthony, T33S R07W S21 and S28. 20 May and 16 June 1993.

KS: Harper Co., Bluff Cr. at Hwy. 179 bridge 2.5 mi. S of Anthony, T34S R07W S01 and S02. 19 July 1992 and 20 May 1993.

KS: Harper Co., Bluff Cr. NW of Bluff City, T34S R06W S10 and S11. 19 July 1992, 20 May and 16 June 1993.

KS: Harper Co., Bluff Cr. N edge of Bluff City, T34S R05W S16. 16 June and 22 July 1993.

KS: Harper Co., Bluff Cr. 1 mi. E of Bluff City, T34S R05W S15 and S22. 19 July 1992 and 22 July 1993.

KS: Sumner Co., Bluff Cr. WSW of Caldwell, T35S R03W S15 and S16. 19 July 1992 and 22 July 1993.

KS: Sumner Co., Fall Cr. SW of Caldwell, T35S R03W S02 and S03. 19 July 1992 and 16 June 1993.

OK: Grant Co., Chikaskia R. at Kansas/Oklahoma state-line, T29N R03W S13. 8 July 1992 and 17 June 1993.

OK: Kay Co., Unnamed Cr. 1 mi. S of Kansas/Oklahoma border on Hwy. 177 then 3 mi. W, T29N R02W S19. 8 July 1992 and 21 July 1993.

OK: Kay Co., Shoo Fly Cr. at low-water crossing, T29N R02W S36. 19 July 1992.

OK: Kay Co., Unnamed Cr., T29N R02W S22 and S27. 14 July 1993.

OK: Kay Co., Bluff Cr. near Blackwell Lake, T29N R02W S19. 22 July 1993.

OK: Kay Co., Chikaskia R. below low-water dam at Blackwell Lake, T29N R02W S34. 8 July 1992 and 21 July 1993.

OK: Kay Co., Dry Cr. at Hwy. 177 bridge NW of Braman, T28N R01W S06. 8 July 1992 and 21 July 1993.

OK: Kay Co., Chikaskia R. at low-water dam 1.75 mi. W and 0.75 mi. S of Braman, T28N R02W S13. 28 July 1992 and 29 July 1993.

OK: Kay Co., Chikaskia R. SW of Braman, T28N R01W and R02W S13 and S18. 1 June and 8 July 1992.

OK: Kay Co., Chikaskia R. 2 mi. N and 1 mi. W of Blackwell, T27N R01W S09. 8 and 28 July 1992.

OK: Kay Co., Chikaskia R. at low-water dam under Hwy. 177 bridge at N edge of Blackwell, T27N R01W S14. 29 July 1993 and 31 May 1994.

OK: Kay Co., Chikaskia R. at SE edge of Blackwell, T27N R01W S25 and S26. 29 July 1993.

OK: Kay Co., Lost Cr. at Hwy. 11 bridge 2 mi. E of Blackwell, T27N R01W S13 and S24. 14 and 21 July 1993.

OK: Kay Co., Chikaskia R. NE of Tonkawa, T26N R01W S36. 8 July 1992.

OK: Kay Co., Chikaskia R. 1.25 mi E of Tonkawa, T25N R01W S01. 28 July 1992.

OK: Kay Co., Chikaskia R. near confluence with Salt Fork of the Arkansas R., T25N R01E S19. 27 July and 28 July 1992.

**Medicine Lodge River,** 24 collections at 9 sites:

KS: Barber Co., Medicine Lodge River 1.0 mi. ENE of Belvidere, T30S R16W S03 and S10. 14 June 1995.

KS: Barber Co., Medicine Lodge R. 0.75 mi. S of Sun City, T31S R15W S02. 7 July 1992, 19 May 1993, 18 March 1994, 14 June and 23 August 1995, 2 January 1997.

KS: Barber Co., Medicine Lodge R. 1 mi. S of Lake City, T31S R14W S14 and S15. 7 July 1992, 19 May 1993, 15 August 1994, 14 June 1995, and 2 January 1997.

KS: Barber Co., Medicine Lodge R. NW of Medicine Lodge, T32S R12W S04. 6 July 1992 and 16 June 1993.

KS: Barber Co., Elm Creek at US Hwy. 160 bridge E edge of Medicine Lodge, T32S R12W S12. 14 June 1995.

KS: Barber Co., Medicine Lodge River 9.0 mi. S and 2.25 mi. E of Medicine Lodge, T33S R11W S21. 7 July 1992, 16 June 1993, and 24 August 1995.

KS: Barber Co., Medicine Lodge R. at Hwy. 2 bridge 1 mi. NE of Kiowa, T34S R11W S36. 16 June 1993 and 18 March 1994.

OK: Alfalfa Co., Medicine Lodge R. at Hwy. 58 bridge 2.5 mi. W of Byron, T28N R11W S24. 23 May 1991, 12 July 1992, and 15 August 1995.

OK: Alfalfa Co., Medicine Lodge River at county road bridge NNE of Cherokee, T27N R11W S01. 15 August 1995.

**Salt Fork of the Arkansas River**, 43 collections at 26 sites:

KS: Comanche Co., Mule Cr. at Hwy. 160 bridge 15.5 mi. E of Coldwater, T32S R16W S03 and S10. 7 July 1992 and 19 May 1993.

KS: Barber Co., Mule Cr. 2.5 mi. N and 1.25 mi. W of Aetna, T33S and T34S R15W S06 and S31. 14 June 1995.

KS: Comanche Co., Nescatunga Cr., T33S and T34S R17W S04 and S33. 13 June and 22 August 1995.

KS: Comanche Co., Salt Fork of the Arkansas R. SSE of Coldwater, T34S R17W S16. 13 June 1995.

KS: Barber Co., Salt Fork of the Arkansas R. 1.25 mi. S of Aetna, T34S R15W S20 and S21. 14 June 1995.

KS: Barber Co., Salt Fork of the Arkansas R. 11.0 mi. W of Hardtner, T35S R14W S16. 13 June 1995.

OK: Woods Co., Salt Fork of the Arkansas River NNW of Alva, T29N R15W S26. 19 June and 22 August 1995.

OK: Woods Co., Salt Fork of the Arkansas River at US Hwy. 281 bridge 0.5 mi. N of Alva, T27N R13W and R14W S13 and S18. 29 July 1993, 16 August 1994, and 19 June 1995.

OK: Alfalfa Co., Salt Fork of the Arkansas River NW of Ingersoll, T27N R11W S17 and S18. 21 August 1995 and 2 January 1997.

OK: Alfalfa Co., Salt Fork of the Arkansas R. at Hwy. 8 bridge 3.5 mi. N of Cherokee, T27N R11W S14. 29 July 1993 and 15 August 1995.

OK: Alfalfa Co., West Branch Salt Fork of the Arkansas R. at Hwy. 11 bridge above Great Salt Plains Reservoir, T27N R10W S23. 12 July 1992.

OK: Alfalfa Co., East Branch Salt Fork of the Arkansas R. at Hwy. 11 bridge above Great Salt Plains Reservoir, T27N R10W S24. 23 May 1991, 12 July 1992, and 15 August 1995.

OK: Alfalfa Co., East Branch Sand Cr. at Hwy. 58 bridge 4.25 mi. E of Byron, T28N R09W S19. 12 July 1992.

OK: Alfalfa Co., Sandy Cr. at Hwy. 11 bridge above Great Salt Plains Reservoir, T27N R09W S19. 12 July 1992.

OK: Alfalfa Co., South end of Great Salt Plains Reservoir, T26N R10W S23. 12 July 1992.

OK: Alfalfa Co., Salt Fork of the Arkansas R. at spillway of Great Salt Plains Reservoir, T26N R09W S11. 12 July 1992 and 1 June 1994.

OK: Grant Co., Salt Fork of the Arkansas River at Hwy. 132 bridge 2.5 mi. N of Nash, T26N R08W S27. 23 May 1991 and 26 July 1994.

OK: Grant Co., Salt Fork of the Arkansas R. 5 mi. E and 3.5 mi. N of Nash, T26N R07W S20 and S21. 27 July 1992.

OK: Grant Co., Salt Fork of the Arkansas R. at Hwy. 81 bridge 2 mi. N of Pond Creek, T26N R06W S35 and S36. 27 July 1992.

OK: Grant Co., Salt Fork of the Arkansas R. at Hwy. 60 bridge E edge of Pond Creek, T25N R06W S01. 20 May 1992 and 27 July 1992.

OK: Grant Co., Salt Fork of the Arkansas R. 3 mi. W and 0.75 mi. N of Salt Fork, T25N R04W S16 and S17. 27 July 1992.

OK: Grant Co., Salt Fork of the Arkansas R. at Hwy. 74 bridge 0.5 mi. N of Salt Fork, T25N R04W S13 and S14. 20 May 1992, 20 July 1994, and 16 October 1996.

OK: Grant Co., Salt Fork of the Arkansas R. 1.5 mi. S of Lamont, T25N R03W S06 and S07. 27 July 1992.

OK: Kay Co., Salt Fork of the Arkansas R. at Hwy. 77 bridge at S edge of Tonkawa, T25N R01W S04. 20 May and 6 October 1992.

OK: Kay Co., Salt Fork of the Arkansas R. at confluence with the Chikaskia R., T25N R01E S19. 27 July and 6 October 1992, 21 February 1996.

OK: Noble Co., Salt Fork of the Arkansas R. at Hwy. 177 bridge 7 mi. S of Ponca City, T24N R02E S10. 6 October 1992.

**Cimarron River**, 103 collections at 47 sites:

KS: Seward Co., Cimarron R. at Hwy. 54 bridge near Arkalon (ghost town), T33S R32W S25. 28 May 1993.

KS: Meade Co., Cimarron R. at Hwy. 23 bridge SW of Meade, T35S R29W S08. 28 May 1993.

KS: Meade Co., Crooked Cr. 13.75 mi. S of Meade, T34S R28W S14. 28 May 1993.

OK: Harper/Woods Co., Cimarron R. at Hwy. 64 bridge 17.0 mi. E of Buffalo, T27N R20W S02. 7 July 1992.

OK: Woods Co., Cimarron R. at US Hwy. 281 Bridge 4.5 mi. S of Waynoka, T24N R16W S35. 18 July 1995.

OK: Major Co., Eagle Chief Cr. NW of Cleo Springs, T23N R12W S35 and

S36. 15 and 29 July 1992.

OK: Major Co., Cimarron R. at Hwy. 8 bridge 2.5 mi. S of Cleo Springs at mouth of Eagle Chief Creek, T22N R12W S23. 15 and 29 July 1992, 17 August 1993, and 14 July 1995.

OK: Major Co., Cimarron River at Hwy. 58 bridge 3 mi. N of Isabella, T21N R10W S19. 22 February 1996.

OK: Major Co., Cimarron R. WSW of Ames on county road, T20N R10W S10 and S15. 21 July and 17 October 1995.

OK: Kingfisher Co., Cimarron R. at Hwy. 51 bridge 8.5 mi. E of Okeene, T19N R09W S16. 17 August 1993 and 14 August 1995.

OK: Kingfisher Co., Cimarron R. at old iron-bridge 2.5 mi. W of Dover, T17N R07W S05. 17 August 1993 and 27 July 1994.

OK: Kingfisher Co., Turkey Cr. 0.5 mi. W of Dover, T17N R07W S02. 15 July 1992.

OK: Kingfisher Co., Cimarron R. at Hwy. 81 bridge 2.0 mi. S of Dover, T17N R07W S14. 15 July 1992.

OK: Logan Co., Cimarron R. at Hwy. 74 bridge 5.0 mi. S of Crescent, T16N R04W S02 and S03. 30 July 1992, 17 August 1993, and 19 July 1995.

OK: Logan Co., Cimarron R. at Hwy. 77 bridge 2.5 mi. N of Guthrie, T17N R02W S28 and S29. 15 and 30 July 1992, 13 July and 17 August 1993, 24 June 1994, and 22 February 1996.

OK: Logan Co., Skeleton Cr. upstream from confluence with Cimarron River, T17N R02W S04. 30 July 1992.

OK: Logan/Payne Co., Cimarron R. at Hwy. 33 bridge 1.0 mi. N of Coyle, T17N R01W S08. 21 and 30 July 1992.

OK: Payne Co., Wild Horse Cr. WNW of Perkins, T18N R01E S15. 11 June 1993.

OK: Payne Co., Wild Horse Cr. at Hwy. 33 bridge 0.75 mi. N and 4.75 mi. W of Perkins, T17N R02E S05. 21 July 1992 and 11 June 1993.

OK: Payne Co., Cimarron R. at Hwy. 177 bridge 0.75 mi. S of Perkins, T17N R03E S07. 21 July 1992 and 13 July 1993.

OK: Payne Co., Dugout Cr. 1.0 mi. S and 1.0 mi. E of Perkins, T17N R03E S07. 13 and 30 July 1993.

OK: Payne Co., Sand Cr. 1.0 mi. S and 5.0 mi. E of Perkins, T17N R03E S11. 30 July 1992.

OK: Payne Co., Cimarron R. at Hwy. 33 bridge 0.75 mi. N and 6.75 mi. E of Perkins, T18N R04E S31. 30 July 1992 and 12 August 1993.

OK: Payne Co., Cimarron R. at confluence with Stillwater Cr., T18N R04E S19. 7 July and 12 August 1993, 15 and 23 June and 4 August 1994.

OK: Payne Co., Cimarron R. at Hwy. 18 bridge 4.75 mi. N of Cushing, T18N R05E S10. 7 July 1993 and 16 May 1994.

OK: Payne Co., Cimarron R. 1.0 mi. S of Yale, T19N R05E S25. 24 June 1993.

OK: Noble Co., North Stillwater Creek SE of Perry, T20N R01E S17 and S18. 15 May 1995.

OK: Payne Co., Stillwater Cr. upstream of Lake Carl Blackwell, T19N R01W S08 and S09. 18 September 1993, 8 June and 2 October 1994, and 15 May 1995.

OK: Payne Co., Stillwater Cr. below spillway of Lake Carl Blackwell, T19N R01E S10. 18 September 1993, 8 June and 2 October 1994, and 15 May 1995.

OK: Payne Co., Stillwater Cr. at old Stillwater Municipal Sewage Plant, T19N R02E S23. 16 May 1995.

OK: Payne Co., Boomer Cr. at low-water dam at Third and Perkins streets in Stillwater, T19N R02E S13. 16 May 1995.

OK: Payne Co., Boomer Cr. at Couch Park in Stillwater, T19N R02E S24. 18 September 1993, 8 June and 2 October 1994, and 15 May 1995.

OK: Payne Co., Stillwater Cr. ESE of Stillwater at mouth of Brush Creek, T19N R03E S29. 18 September 1993 and 8 June 1994.

OK: Payne Co., Stillwater Cr. SE of Stillwater, T19N R03E S32 and S33. 28 July 1993.

OK: Payne Co., Little Stillwater Cr. 4.0 mi. E, 2.0 mi. S, and 0.25 mi. E of Stillwater, T19N R04E S36. 21 September 1993, 8 June and 2 October 1994, and 15 May 1995.

OK: Payne Co., Stillwater Cr. near confluence with Cimarron R., T18N R04E S19. 21 September 1993 and 15 June 1994.

OK: Payne Co., Council Cr. 3.0 mi. S and 0.75 mi. E of Glencoe, T20N R04E S31. 20 March and 9 June 1993, 16 May 1994, and 9 August 1995.

OK: Payne Co., Council Cr. 6.5 mi. S and 2.5 mi. E of Glencoe, T19N R04E S09. 20 March and 9 June 1993, 16 May 1994, and 9 August 1995.

OK: Payne Co., Council Cr. at Hwy. 51 bridge 10.0 mi. E of Stillwater, T19N R04E S15 and S22. 20 March, 9 June, and 24 June 1993, 16 May 1994, 15 June and 9 August 1995.

OK: Payne Co., Council Cr. 6.0 mi. N and 2.0 mi. W of Cushing, T19N R05E S05 and S32. 20 March and 9 June 1993, 16 May 1994, and 9 August 1995.

OK: Payne/Pawnee Co., Salt Cr. above and below bridge on county line, T20N R04E S25 and T20N R05E S30. 16 July 1993 and 15 June 1995.

OK: Payne Co., Salt Cr. at Hwy. 18 bridge, T19N R05E S04 and S05. 16 July 1993 and 15 June 1995.

OK: Payne Co., Salt Cr. at old Hwy. 51 bridge, T19N R05E S10 and S15.

16 July 1993.

**OK:** Payne Co., Salt Cr. at Hwy. 51 bridge 1.25 mi. W of Yale, T19N R05E S23. 24 June and 16 July 1993.

OK: Creek Co., Unnamed Cr. at Hwy. 99 bridge 1.25 mi. S of Oilton, T18N R07E S08. 7 and 16 July 1993.

OK: Creek Co., Cimarron R. 1.0 mi. S and 1.0 mi. W of Oilton, T18N R07E S08. 7 July 1993.

OK: Creek Co., Cimarron R. at Hwy. 99 bridge 0.5 mi. N of Oilton, T19N R07E S28. 7 July 1993.

**Canadian River**, 1 collection at 1 site:

OK: Haskell/Muskogee Co., Canadian R. at Hwy. 2 bridge N edge of Whitefield, T09N R20E S07. 27 July 1993.

**Deep Fork River**, 7 collections at 7 sites:

OK: Lincoln Co., Deep Fork R. at Hwy. 177 bridge N edge of Warwick, T14N R03E S17. 12 September 1993.

OK: Lincoln Co., Deep Fork R. at Hwy. 66 bridge E edge of Warwick, T14N R03E S20. 18 August 1991.

OK: Lincoln Co., Deep Fork R. at Hwy. 18 bridge 3.25 mi. S of Chandler, T14N R04E S33. 18 August 1991.

OK: Lincoln Co., Deep Fork R. at Hwy. 99 bridge 3 mi. S of Stroud, T14N R06E S15 and S16. 18 August 1991.

OK: Creek Co., Little Deep Fork R. 0.25 mi. S of Slick, T15N R10E S17. 18 August 1991.

OK: Okmulgee Co., Deep Fork R. at Hwy. 56 bridge 3 mi. W of Okmulgee, T13N R12E S10. 18 August 1991.

OK: Okmulgee Co., Deep Fork R. at Hwy. 75 bridge 2 mi. S of Okmulgee, T13N R13E S29. 18 August 1991.

**North Canadian River**, 17 collections at 16 sites:

OK: Texas Co., Palo Duro Cr. at Hwy. 3 bridge 9.25 mi. E of Hardesty, T02N R19E S21 and S28. 30 July 1992.

OK: Beaver Co., Beaver R. at Hwy. 83 bridge 7 mi. S of Turpin, T03N R21E S06. 30 July 1992.

OK: Beaver Co., Beaver R. at Hwy. 270 bridge N edge of Beaver, T14N R24E S07. 29 July 1992.

OK: Harper Co., Beaver R. at Hwy. 283 bridge 2.75 mi. N of Laverne, T26N R25W S09 and S10. 29 July 1992.

OK: Harper Co., Kiowa Cr. 5 mi. W and 2 mi. N of Laverne, T26N R26W S14 and S15. 29 July 1992.

OK: Woodward Co., North Canadian R. at Hwy. 34 bridge N edge of Woodward, T23N R20W and R21W S25 and S30. 7 July 1992.

OK: Woodward Co., North Canadian R 5.5. mi. E of Woodward at US Hwy. 412 bridge; T23N R19W S30. 17 August 1995.

OK: Blaine Co., North Canadian R. in spillway of Canton Reservoir, T19N R13W S33. 17 August 1993.

OK: Blaine Co., North Canadian R. at Hwy. 270 bridge 2 mi. W of Watonga, T16N R12W S22 and S27. 20 July 1992.

OK: Canadian Co., North Canadian R. at Hwy. 81 bridge 1 mi. N of El Reno, T13N R07W S33. 20 July 1992.

OK: Oklahoma Co., North Canadian R. at Hwy. 62 bridge NW edge of Midwest City, T12N R02W S20 and S29. 20 July 1992.

OK: Oklahoma Co., North Canadian R. at Hwy. 62 bridge NE edge of Harrah, T12N R01E S23, S25, and S26. 20 July 1992 and 1 August 1994.

OK: Pottawatomie Co., North Canadian R. at Hwy. 177 bridge near Shawnee, T10N R03E S25. 26 July 1993.

OK: Okfuskee Co., North Canadian R. 6 mi. S of Okemah at State Hwy. 27 bridge; T10N R09E S13 and T10N R10E S18. 4 August 1994.

OK: McIntosh Co., North Canadian R. at Indian Nations Turnpike, T10N R13E S29. 11 September 1993.

OK: Okmulgee Co., North Canadian R. 5 mi. E, 4 mi. S, and 1.5 mi. E of Henryetta, T11N R13E S36. 27 July 1993.

**South Canadian River**, 18 collections at 13 sites:

NM: Quay Co., South Canadian River near Logan. 1 September 1996.

TX: Oldham Co., South Canadian R. at US Hwy. 385 bridge near Boy's Ranch. 11 July 1995 and 2 September 1996.

TX: Hemphill Co., Canadian River at Hwy. 60 and 83 bridge N of Canadian. 12 July 1995.

OK: Ellis Co., South Canadian R. at US Hwy. 283 bridge 18 mi. S of Arnett, T16N R24W S10, S14, and S15. 28 June 1995.

OK: Dewey Co., South Canadian R. 0.75 mi. N of Taloga at US Hwy. 183 bridge, T18N R17W S12. 9 July 1992 and 27 June 1995.

OK: Custer Co., South Canadian R. at State Hwy. 33 bridge NE of Thomas, T15N R14W S15. 30 June 1995.

OK: Caddo Co., South Canadian R. at US Hwy. 281 bridge 0.5 mi. S and 4 mi. E of Bridgeport, T12N R11W S01. 9 July 1992 and 18 August 1994.

OK: McClain/Cleveland Co., South Canadian R. at Hwy. I44 bridge 3.5 mi. N of Newcastle, T10N R04W S34 and S35. 9 July 1992.

OK: McClain/Cleveland Co., South Canadian R. at US Hwy. 77 bridge between Lexington and Purcell, T06N R01W S06 and S07. 26 July 1993 and 28 July 1994.

OK: Pottawatomie/Pontotoc Co., South Canadian R. at Hwy. 177 bridge 1.5 mi. S of Asher, T06N R04E S30. 12 September 1993.

OK: Seminole/Pontotoc Co., South Canadian R. at Hwy. 99 bridge 3.5 mi. N of Byng, T05N R06E S04. 12 September 1993.

OK: Hughes Co., South Canadian R. at US Hwy. 75 bridge NE edge of Calvin, T06N R10E S22. 26 July 1993 and 21 July 1994.

OK: McIntosh/Pittsburg Co., South Canadian R. at Indian Nations Turnpike, T08N R13E S23. 11 September 1993.

# APPENDIX C

Location and legal descriptions for 24 habitat study sites sampled in 1994 and 1995. Sites are listed in upstream-downstream order within stream. See Figure 6 for map locations.

Stream:
State: County, Location. Date.

Cimarron River:

OK: Woods Co., 4.5 mi. S of Waynoka at US Hwy. 281 bridge, T24N R16W S35. 18 July 1995.

OK: Major Co., 2.5 mi. S of Cleo Springs at State Hwy. 8 bridge, T22N R12W S23. 14 July 1995.

OK: Major Co., WSW of Ames on county road, T20N R10W S10 and S15. 21 July 1995.

OK: Kingfisher Co., 8.5 mi. E of Okeene at State Hwy. 51 bridge, T19N R09W S16. 14 August 1995.

OK: Kingfisher Co., 2.5 mi. W of Dover at old-iron bridge, T17N R07W S04 and S05. 27 July 1994.

OK: Logan Co., 2.5 mi. N of Guthrie at US Hwy. 77 bridge, T17N R02W S28 and S29. 24 June 1994.

OK: Payne Co., near confluence with Stillwater Creek, T18N R04E S19. 23 June 1994.

Medicine Lodge River:

KS: Barber Co., 0.75 mi. S of Sun City, T31S R15W S02. 23 August 1995.

KS: Barber Co., 1 mi. S of Lake City on gravel road, T31S R14W S14 and S15. 15 August 1994.

KS: Barber Co., 9 mi. S and 2.25 mi. E of Medicine Lodge, T33S R11W S21. 24 August 1995.

North Canadian River:

OK: Woodward Co., 5.5. mi. E of Woodward at US Hwy. 412 bridge, T23N R19W S30. 17 August 1995.

OK: Oklahoma Co., US Hwy. 62 bridge at NE corner of Harrah, T12N R01E S23, S25, and S26. 1 August 1994.

OK: Okfuskee Co., 6 mi. S of Okemah at State Hwy. 27 bridge, T10N R09E S13 and T10N R10E S18. 4 August 1994.

South Canadian River:

OK: Ellis Co., 18 mi. S of Arnett at US Hwy. 283 bridge, T16N R24W S10, S14, and S15. 28 June 1995.

OK: Dewey Co., 0.75 mi. N of Taloga at US Hwy. 183 bridge, T18N R17W S12. 27 June 1995.

OK: Custer Co., NE of Thomas at State Hwy. 33 bridge, T15N R14W S15. 30 June 1995.

OK: Caddo Co., 0.5 mi. S and 4 mi. E of Bridgeport at US Hwy. 281 bridge, T12N R11W S01. 18 August 1994.

OK: McClain/Cleveland Co., US Hwy. 77 bridge between Lexington and Purcell, T06N R01W S06 and S07. 28 July 1994.

OK: Hughes Co., NE edge of Calvin at US Hwy. 75 bridge, T06N R10E S22. 21 July 1994.

Salt Fork of the Arkansas River:

OK: Woods Co., NNW of Alva on county road, T29N R15W S26. 22 August 1995.

OK: Woods Co., 0.5 mi. N of Alva at US Hwy. 281 bridge, T27N R13W S18, and T27N R14W S13. 16 August 1994.

OK: Alfalfa Co., NW of Ingersoll on county road, T27N R11W S17 and S18. 21 August 1995.

OK: Grant Co., 2.5 mi. N of Nash at State Hwy. 132 bridge, T26N R08W S27. 26 July 1994.

OK: Grant Co., 0.5 mi. N of Salt Fork at State Hwy. 74 bridge, T25N R04W S13 and S14. 20 July 1994.

## APPENDIX D

Seine-collections made subsequent to reintroduction of speckled chub. Site numbers correspond with Figure 12.

Site) State: County, Stream locality. Collection date(s).

1) KS: Comanche Co., Nescatunga Creek, T33S and T34S R17W S04 and S33. 13 June and 22 August 1995.

2) KS: Comanche Co., Salt Fork of the Arkansas River SSE of Coldwater, T34S R17W S16. 13 June 1995.

3) KS: Barber Co., Mule Creek 2.5 mi. N and 1.25 mi. W of Aetna, T33S and T34S R15W S06 and S31. 14 June 1995.

4) KS: Barber Co., Salt Fork of the Arkansas River 1.25 mi. S of Aetna, T34S R15W S20 and S21. 14 June 1995.

5) KS: Barber Co., Salt Fork of the Arkansas River 11.0 mi. W of Hardtner, T35S R14W S16. 13 June 1995.

6) OK: Woods Co., Salt Fork of the Arkansas River NNW of Alva, T29N R15W S26. 19 June and 22 August 1995.

7) OK: Woods Co., Salt Fork of the Arkansas River at US Hwy. 281 bridge 0.5 mi. N of Alva, T27N R13W and R14W S13 and S18. 16 August 1994 and 19 June 1995.

8) OK: Alfalfa Co., Salt Fork of the Arkansas River at Hwy. 8 bridge 3.5 mi. N of Cherokee, T27N R11W S14. 15 August 1995.

9) OK: Alfalfa Co., Salt Fork of the Arkansas River NW of Ingersoll, T27N R11W S17 and S18. 21 August 1995 and 2 January 1997.

10) KS: Barber Co., Medicine Lodge River 1.0 mi. ENE of Belvidere, T30S R16W S03 and S10. 14 June 1995.

11) KS: Barber Co., Medicine Lodge River 0.75 mi. S of Sun City, T31S R15W S02. 14 June and 23 August 1995, 2 January 1997.

12) KS: Barber Co., Medicine Lodge River 1.0 mi. S of Lake City, T31S R14W S14. 15 August 1994, 14 June 1995, and 2 January 1997.

13) KS: Barber Co., Elm Creek at US Hwy. 160 bridge E edge of Medicine Lodge, T32S R12W S12. 14 June 1995.

14) KS: Barber Co., Medicine Lodge River 9.0 mi. S and 2.25 mi. E of Medicine Lodge, T33S R11W S21. 24 August 1995.

15) OK: Alfalfa Co., Medicine Lodge River at Hwy. 58 bridge 2.5 mi. W of Byron, T28N R11W S24. 15 August 1995.

16) OK: Alfalfa Co., Medicine Lodge River at county road bridge NNE of Cherokee, T27N R11W S01. 15 August 1995.

17) OK: Alfalfa Co., Salt Fork of the Arkansas River at Hwy. 11 bridge, T27N R10W S24. 15 August 1995.

18) OK: Grant Co., Salt Fork of the Arkansas River at Hwy. 132 bridge 2.5

mi. N of Nash, T26N R08W S27. 26 July 1994.

19) OK: Grant Co., Salt Fork of the Arkansas River at Hwy. 74 bridge 0.5 mi. N of Salt Fork, T25N R04W S13 and S14. 20 July 1994.

2

# VITA

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Doctor of Philosophy

Thesis: CONSERVATION BIOLOGY OF THE SPECKLED CHUB COMPLEX (CYPRINIDAE: CF. *MACRHYBOPSIS AESTIVALIS*) IN THE ARKANSAS RIVER BASIN

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